Estimating the 1998 Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Escapement, with Special Reference to the Effect of Migration Stress on Estimation Accuracy

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by

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ABSTRACT

Schubert, N.D., and Houtman, R. 2007. Estimating the 1998 Fraser River sockeye salmon (*Oncorhynchus nerka*) escapement, with special reference to the effect of migration stress on estimation accuracy. Can. Tech. Rep. Fish. Aquat. Sci. 2732: ix + 121 p.

The Department of Fisheries and Oceans conducts annual assessments of the abundance of Fraser River sockeye salmon (*Oncorhynchus nerka*) populations on the spawning grounds. Large populations (25,000+) are assessed using enumeration fences or mark-recapture studies, while small populations (less than 25,000) are assessed using visual techniques. In 1998, study techniques included tagging and recovery (mark-recapture), enumeration fences, counts in artificial spawning channels and visual surveys. The escapement totalled 4,422,075 adults and 5,604 jacks distributed over 172 populations in ten geographic areas and four run timing groups. The proportion that was estimated by each study type was 87% by mark-recapture projects (overall precision of ±3%), 7% at enumeration fences, 2% at spawning channels and 4% by visual surveys. Estimation bias cannot be quantified, but evidence is presented in support of the conclusion that overall bias in the 1998 estimates is minor.

Understanding the potential biases associated with mark-recapture studies is critical because the technique is used to estimate a large proportion of the total escapement. A new three-step process evaluates: study design execution; biases in complementary two-sample data stratifications; and differences between the maximum likelihood Darroch and pooled Petersen estimates. The detection of bi-directional (positive and negative) biases in 1998 is inconsistent with the traditional bias structure in sockeye mark-recapture studies where positive biases are most common. Such positive biases result from a decreasing probability of tagging of individual sockeye with the distance upstream that they spawn, coupled with a complementary increasing probability of recovery. Improvements in study designs since 1994 have made tag incidence spatially more representative and have changed the bias structure of the estimates relative to previous years. Further refinements in the analytic process are required to quantify the size of study-specific bias

In 1998, Fraser River sockeye were exposed to record low water levels and record high water temperatures on their spawning migration, conditions that can change their behaviour and introduce bias in the population estimates. The mark-recapture technique is especially vulnerable to such bias because it requires the handling of the fish. A detailed stress assessment is used to determine whether the fish were in poor condition when they arrived on the spawning grounds, and whether handling stress represents a 'last straw' by altering their subsequent behaviour or survival, and their probability of recovery following spawning. To assess arrival condition, four factors are compared with previous years: the proportion of the sockeye that required ventilation after tagging; the proportion recaptured at the tag site; time between tagging and carcass recovery; and average female spawning success. Despite the adverse migratory route conditions, there is little evidence that fish arrived on the spawning grounds in poor condition except for the Stuart Early Run, where more fish required ventilation at release, the post-tagging life-span was reduced, and spawning success was low. To assess the 'last straw' effect, three factors are evaluated: recovery rates of tagged fish that required ventilation or were recaptured at the tag site; spawning success of tagged versus untagged fish; and the recovery distributions of tagged versus untagged fish. There is little evidence that the incremental handling stress from the mark-recapture process introduced bias in the escapement estimates.

RÉSUMÉ

Schubert, N.D. and Houtman, R. 2007. Estimating the 1998 Fraser River sockeye salmon (*Oncorhynchus nerka*) escapement, with special reference to the effect of migration stress on estimation accuracy. Can. Tech. Rep. Fish. Aquat. Sci. 2732: ix + 121 p.

Le ministère des Pêches et des Océans évalue chaque année l'abondance des populations de saumon rouge (*Oncorhynchus nerka*) du fleuve Fraser dans les aires de fraie. Les grandes populations (25 000 saumons et plus) sont évaluées au moyen de barrières de dénombrement ou d'études de marquage-recapture, tandis que les petites populations (moins de 25 000 saumons) sont évaluées à l'aide de techniques visuelles. En 1998, les techniques d'étude comprenaient le marquage et la recapture, l'utilisation de barrières de dénombrement, le dénombrement dans des frayères artificielles et le relevé visuel. L'échappée totale s'est chiffrée à 4 422 075 adultes et 5 604 madeleineaux de 172 populations dans dix zones géographiques et quatre groupes de montaison. Chaque technique d'étude a été utilisée pour évaluer une certaine proportion de l'échappée : études de marquage-recapture - 87 % (précision générale de ±3 %), barrières de dénombrement - 7 %, frayères artificielles - 2 % et relevés visuels - 4 %. Le biais dans les estimations ne peut être quantifié, mais des données sont présentées à l'appui de la conclusion selon laquelle le biais général dans les estimations de 1998 est petit.

La compréhension des biais possibles associés aux études de marquage-recapture est essentielle puisque la technique est utilisée pour estimer une grande partie de l'échappée totale. Un nouveau processus en trois étapes évalue la réalisation du plan expérimental, les biais dans les données sur deux échantillons complémentaires et les différences entre l'estimateur de Darroch de vraisemblance maximale et l'estimateur cumulé de Petersen. La détection de biais bidirectionnels (positifs et négatifs) en 1998 ne concorde pas avec la structure de biais traditionnelle dans les études de marquage-recapture du saumon rouge, où les biais positifs sont les plus courants. De tels biais positifs sont le résultat d'une baisse de la probabilité de marquage de saumons individuels quand la distance du lieu de fraie en amont augmente, et cette baisse est combinée à une hausse complémentaire de la probabilité de recapture. Les améliorations apportées aux plans expérimentaux depuis 1994 ont fait en sorte que les cas de signalement de marques sont maintenant plus représentatifs sur le plan spatial et elles ont entraîné une modification de la structure de biais des estimations par rapport aux années précédentes. Le processus d'analyse doit faire l'objet de nouvelles améliorations afin de quantifier le biais propre à chaque étude.

En 1998, les saumons rouges du Fraser ont fait face à des records de faible niveau d'eau et de haute température de l'eau durant leur migration de reproduction. Ces conditions peuvent modifier le comportement des saumons et entraîner des biais dans les estimations des populations. La technique de marquage-recapture est particulièrement vulnérable à de tels biais parce qu'elle nécessite la manipulation des poissons. Une évaluation détaillée du stress est utilisée pour déterminer si les poissons étaient en mauvaise condition au moment de leur arrivée sur les lieux de fraie et si le stress dû à la manipulation représente la « dernière goutte » en modifiant le comportement et la survie des saumons, de même que la probabilité de recapture après la fraie. Pour évaluer la condition des saumons à leur arrivée, quatre facteurs font l'objet d'une comparaison avec les données des années précédentes : la proportion de saumons rouges qui ont dû être oxygénés après le marquage; la proportion de saumons recapturés au site de marquage; la période entre le marquage et la récupération de carcasses; le taux de succès de reproduction moyen des femelles. Malgré les conditions défavorables le long de la voie migratoire, très peu d'indices suggèrent que les saumons sont arrivés sur les lieux de fraie en mauvaise condition, à l'exception de la remonte précoce dans la rivière Stuart, où davantage de poissons ont eu besoin d'être oxygénés avant leur remise à l'eau, la durée de vie après le marquage était réduite et le succès de reproduction était faible. Pour évaluer l'effet de la « dernière goutte », trois facteurs sont évalués : les taux de récupération des poissons marqués qui ont eu besoin d'être oxygénés ou qui ont été recapturés au site de marquage; le succès de reproduction des poissons marqués par rapport à celui des poissons non marqués; la comparaison de la distribution des poissons marqués récupérés et des poissons non marqués récupérés. Il existe peu de preuves que le stress supplémentaire dû à la manipulation durant le processus de marquage-recapture entraîne un biais dans les estimations des échappées.

INTRODUCTION

The Fraser River system supports the largest population of sockeye salmon *(Oncorhynchus nerka)* in the world (Northcote and Larkin 1989). Sockeye spawn in over 150 natal areas, ranging from small streams to large rivers and lakes, that are distributed throughout the accessible portion of the Fraser system. In the early decades of the twentieth century, spawner abundance was estimated by fisheries agencies of the Government of Canada using visual techniques that were often poorly suited to the populations and the spawning grounds. In 1938, resources became available for the development of improved estimation techniques after the International Pacific Salmon Fisheries Commission (IPSFC) assumed responsibility for the management and assessment of the Fraser River sockeye salmon resource. The IPSFC's early work, described by Atkinson (1944), Howard (1948) and Schaefer (1951), led to the development of a two tiered escapement estimation system whereby the method selected for each stock was based on the number of spawners expected to return in a given year (Woodey 1984; Andrew and Webb 1987). For stocks with small expected returns (less than 25,000), a variety of stock-specific visual estimation methods were used. For stocks with large expected returns (more than 25,000), enumeration fences and mark-recapture studies were used. The Department of Fisheries and Oceans (DFO), which reassumed responsibility for the estimation of sockeye salmon escapements with the signing of the Pacific Salmon Treaty in 1985, recognized the importance of maintaining consistent estimation methods by adopting the system developed by the IPSFC. These methods, adapted to address study deign deficiencies and increased escapements (Schubert 1998, 2007), remain largely in place throughout the Fraser River system.

The annual plan for the estimation of Fraser River sockeye escapements is developed from preseason forecasts of abundance provided by DFO's stock assessment sector, and stock-specific harvest rates estimated from the preseason fishing plan provided by DFO's fisheries management Sector. The 1998 plan was based on an expectation that over six million sockeye would return to spawn. Large escapements were expected for the sub-dominant cycle Summer Run and dominant cycle Late Run stocks. Consequently, the plan included a number of enumeration fences (11) and mark-recapture studies (13), with the balance of the stocks (148) assessed using visual methods. In this report, we document the 1998 survey methods, analytic procedures, and results, including an evaluation of estimation precision and bias for each of the techniques.

The procedures used to estimate population size from mark-recapture data and to assess sampling selectivity are described by Schubert (1998). They are further refined in this technical report to better evaluate estimation bias and the potential effects of stress on estimation accuracy. Because the fish experienced adverse conditions caused by low flows and high water temperatures along the migratory route in 1998, we compile a stress profile for each population for comparison with previous years to assess whether the potential impacts are sufficient to introduce bias in the population estimates. We conclude with an evaluation of the overall accuracy and direction of biases in the 1998 estimates.

STOCK DESCRIPTION

Fraser River sockeye migrate to spawning areas located from tidal influence to as far upstream as 1,270 km (Fig. 1). Nine stocks or stock groups (Birkenhead, Weaver, Chilko, Quesnel, Stellako, Stuart (Early and Summer runs), Adams and Shuswap) account for the majority of the system's production. The predominant age at maturity for Fraser River sockeye is four years; consequently, many stocks exhibit a pronounced quadrennial escapement cycle, with a strong dominant year, an intermediate subdominant year, and two weak years. In 1998, the Weaver, Adams and Shuswap stocks were in their dominant year, the Stuart and Quesnel Summer Run stocks were in their subdominant year, and the Stuart Early Run stock was in an off-cycle year; Birkenhead, Chilko and Stellako do not exhibit a strongly cyclic pattern.

Because the size of the watershed is vast (223,000 km^2) and the spawning migration protracted (June to October), we aggregate the stocks into ten geographic groups based on the major sub-basins of the Fraser River, and four run timing groups based on the time of entry into the lower Fraser River. The geographic groups (and the number of constituent stocks) are: Lower Fraser (tributaries of the Fraser River from the mouth to the Thompson River, excluding the

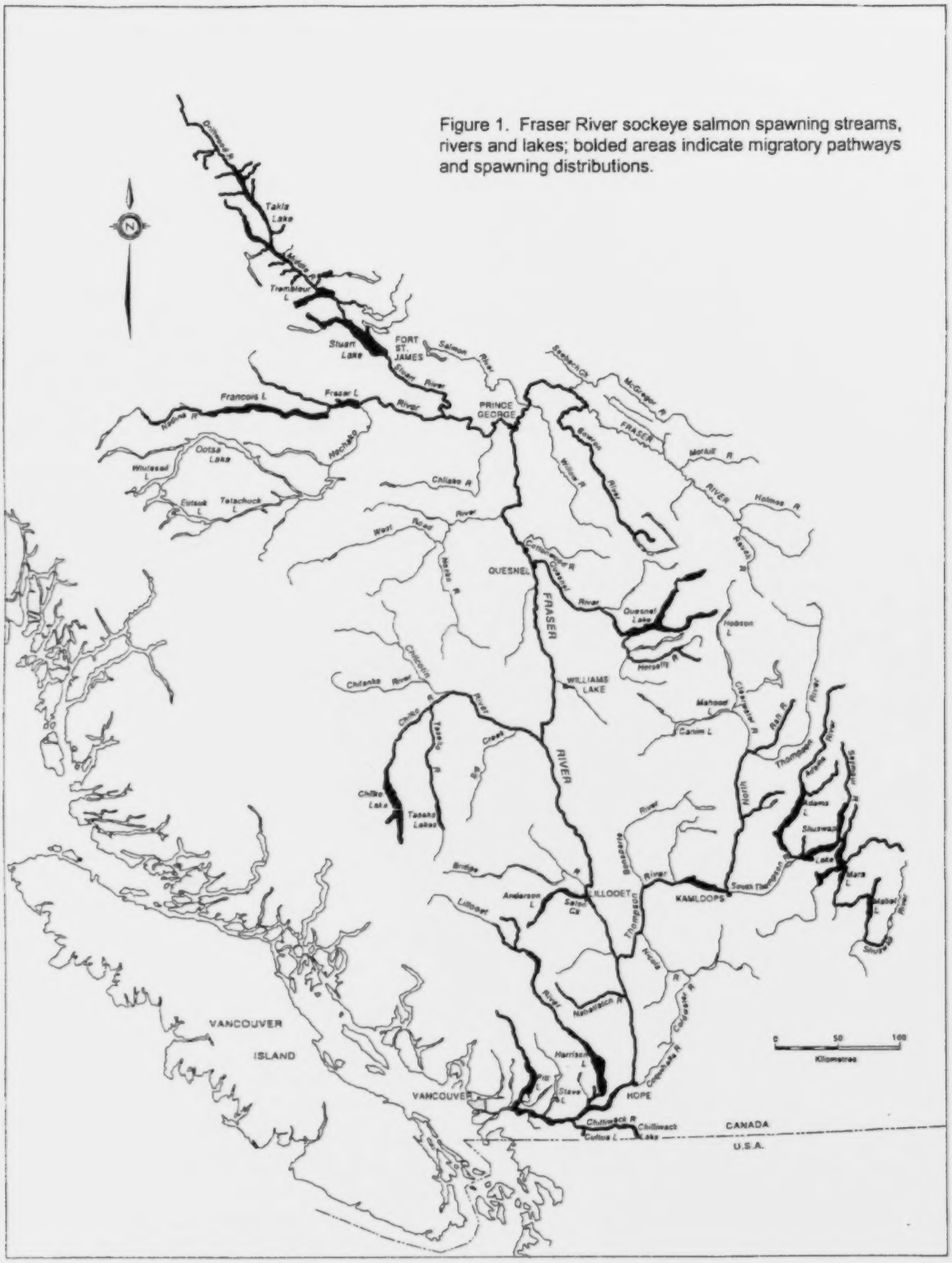


Figure 1. Fraser River sockeye salmon spawning streams, rivers and lakes; bolded areas indicate migratory pathways and spawning distributions.

Harrison-Lillooet) (5); Harrison-Lillooet (7); Seton-Anderson (2); South Thompson Early Summer (19) and Late (30) runs; North Thompson (3); Chilcotin (3); Quesnel (47); Stuart Early (38) and Summer (7) runs; Nechako (2); and Upper Fraser (tributaries of the Fraser River upstream from the Nechako River) (2). The constituent stocks are listed for each group in Table 1.

The run timing groups were established for fishery management purposes and consist of stocks with similar migratory timing during their return from the ocean to the spawning grounds. The Early Run, commonly termed the Early Stuart Run, consists of 38 stocks that spawn in the Stuart River system; the run arrives in the lower Fraser River from late June to late July. The Early Summer Run, which consists of 32 stocks that spawn throughout the Fraser system, arrives in the river from mid July to mid August. The Summer Run, which consists of 57 stocks that spawn in the Chilko, Quesnel, Stellako and Stuart systems, arrives in the river from mid July to early September. The Late Run, which consists of 52 stocks that spawn in the lower Fraser, Harrison-Lillooet, Thompson and Seton-Anderson systems, arrives in the river from August to mid October. The constituent stocks are listed for each group in Table 2.

METHODS

This section describes the arrival indices, that monitor run timing and relative abundance near the spawning grounds, and three spawner estimation techniques: mark-recapture studies that are used to estimate the escapement of the largest stocks; enumeration fences that are used in spawning channels, and in rivers with appropriate morphology and when funds are available; and stream surveys, where visual counts or estimates of live and dead spawners are expanded to estimate escapement.

ARRIVAL INDICES

The 1998 arrival indices are based on observations from bridges across the Chilko, Quesnel, Little, and Shuswap rivers, and from a tower at the Adams River mouth. They provide fishery managers an early indicator of the impact of management actions, and mark-recapture staff a means to establish daily tagging targets.

The arrival patterns of the major stocks are observed from a tower, or from bridges that are suitably located below the lower limit of spawning and when the height of the bridge and the colour and depth of the water permit accurate counts. Sockeye tend to migrate along the bank in a single, relatively narrow column where they can be easily counted by an observer stationed above the shoreline. Counts are made for 15 minutes each half hour and reported as a daily average. In some cases (*e.g.* Chilko), managers expand the counts by a constant to generate a rough estimate of escapement.

MARK-RECAPTURE STUDIES

In 1998, mark-recapture studies were used to estimate the escapement of three Early Summer Run stocks, Eagle, Pitt and Seymour, five Summer Run stocks, Chilko, Horsefly, Middle, Mitchell and Tachie, and five Late Run stocks, Adams, Birkenhead, Little, Shuswap, and Weaver. An additional Summer Run stock, the Stellako, is estimated by mark-recapture as part of a study comparing fence and mark-recapture estimates.

This section describes general study objectives, operational and analytic procedures, and specific procedures for the 13 mark-recapture studies conducted in 1998. In general, the studies designs are similar to those described in the final report of the Fraser River Sockeye Public Review Board's (FRSPRB) Spawning Escapement Estimation Working Group (Anon. 1995a). Exceptions are changes that address specific study design deficiencies identified in 1994 and subsequent years, including:

- Increasing the temporal and spatial coverage of the application and recovery surveys to ensure they encompass the entire period of arrival and die-off, respectively;
- Increasing the frequency and extent of the resurvey, and developing procedures to incorporate its variance into that of the population estimator;
- Applying a secondary tag to all tagged fish to permit the assessment of tag loss;
- Improving handling procedures to reduce fish stress and permit its assessment;
- Modifying fish capture procedures and the number and location of tagging sites to make more representative the spatial and temporal distribution of tags;
- Other changes implemented to address study-specific issues.

Table 1. List of Fraser River sockeye salmon stocks by geographic group.[a]

Fraser River sockeye stocks by geographic area

Lower Fraser
Early Summer and Late Run
Chilliwack Lake
Cultus Lake
Nahatlatch Lake
Nahatlatch River
Pitt River, upper
Widgeon Slough

Harrison-Lillooet
Late Run
Big Silver Creek
Birkenhead River
Green River
Harrison River
Poole Creek
Samson Creek
Weaver Channel
Weaver Creek

Seton-Anderson
Early Summer and Late Run
Gates Channel
Gates Creek
Portage Creek

South Thompson
Early Summer Run
Adams Channel
Adams River, lower
Adams River, upper
Anstey River
Cayenne Creek
Celista Creek
Eagle River
Hiuihill Creek
Hunakwa Creek
Malakwa Creek
McNomee Creek
Momich River
Nikwikwaia Creek
Onyx Creek
Perry River
Ross Creek
Salmon River
Scotch Creek
Seymour River
Yard Creek

South Thompson
Late Run
Adams Lake
Adams River, lower
Adams River, upper
Anstey River
Bush Creek
Canoe Creek
Celista Creek
Eagle River
Hiuihill Creek
Hunakwa Creek
Little River
McNomee Creek
Momich River
Nikwikwaia Creek
Pass Creek
Perry River
Salmon River
Scotch Creek
Seymour River
South Thompson River
Tappen Creek
Yard Creek
Shuswap Lake
Anstey Arm
Main Arm
Salmon Arm
Seymour Arm
Shuswap River
Shuswap River, lower
Shuswap River, middle
Tsuius Creek
Wap Creek

North Thompson
Early Summer Run
Fennell Creek
Harper Creek
Raft River

Chilcotin
Summer Run
Chilko River and Lake
Elkin Creek
Taseko Lake

Quesnel
Summer Run
Horsefly River
Horsefly Channel
Horsefly River
Little Horsefly River
McKinley Creek
Moffat Creek
Mitchell River
Cameron Creek
Mitchell River
Penfold Creek
Quesnel Lake, E Arm
Big Slide Lakeshore
Bill Miner Creek
Bill Miner Lakeshore
Blue Lead Creek
Blue Lead Lakeshore
Bouldery Creek
Bouldery Lakeshore
Bouldery Lakeshore, 2 km W
Killdog Creek
Lynx Creek
Lynx Lakeshore
Niagara Creek
Slate Bay Lakeshore
Summit Creek
Taku Creek
Quesnel Lake, N Arm
Bear Beach Lakshore
Betty Frank's Lakeshore
Bowling Point Lakeshore
Deception Point Lakeshore
Devoe Creek
Devoe Lakeshore
Goose Point Lakeshore
Grain Creek
Grain Lakeshore
Isaiah Creek
Limestone Point Lakeshore
Long Creek
Long Lakeshore
Marten Creek
Marten Lakeshore
Roaring River
Roaring Lakeshore
Sue Creek
Trickle Creek
Wasko Creek
Watt Creek
Watt Lakeshore
Quesnel Lake, W Arm
Hazeltine Creek
Raft Creek
Spusks Lakeshore

Stuart
Early Run
Driftwood River
Blackwater River
Driftwood River
Kastberg Creek
Kotsine River
Lion Creek
Porter Creek
Takla Lake, NE Arm
Ankwill Creek
Bates Creek
Blanchette Creek
Forsythe Creek
French Creek
Frypan Creek
Hudson's Bay Creek
Shale Creek
Five Mile Creek
Ten Mile Creek
Fifteen Mile Creek
Twenty-five Mile Creek
Takla Lake, NW Arm
Crow Creek
Dust Creek
Hooker Creek
McDougall Creek
Point Creek
Sinta Creek
Takla Lake, Main Arm
Bivouac Creek
Gluske Creek
Leo Creek
Narrows Creek
Sakeniche River
Sandpoint Creek
Middle River
Forfar Creek
Kazchek Creek
Kynock Creek
Middle River
Rossette Creek
Trembleur Lake
Felix Creek
Fleming Creek
Paula Creek
Stuart
Summer Run
Kazchek Creek
Kuzkwa River
Middle River
Pinchi Creek
Sakeniche River
Sowchea Creek
Tachie River

Nechako
Early Summer and Summer Run
Nadina Channel
Nadina River
Stellako River

Upper Fraser
Early Summer Run
Bowron River
Indianpoint Creek

[a] Excludes streams with a record of intermittent escapements that were not surveyed in 1998.

Table 2. List of Fraser River sockeye salmon stocks by run timing group. [a]

Early Run	Early Summer Run	Summer Run			Late Run
Stuart	***Lower Fraser***	***Quesnel***	Grain Creek	***Chilcotin***	***Lower Fraser***
Driftwood River	Chilliwack Lake	*Horsefly River*	Grain Lakeshore	Chilko River and Lake	Cultus Lake
Blackwater River	Nahatlatch Lake	Horsefly Channel	Isaiah Creek		Widgeon Slough
Driftwood River	Nahatlatch River	Horsefly River	Limestone Point Lakeshore	***Stuart***	
Kastberg Creek	Pitt River, upper	Little Horsefly River	Long Creek	Kazchek Creek	***Harrison-Lillooet***
Kotsine River		McKinley Creek	Long Lakeshore	Kuzkwa River	Big Silver Creek
Lion Creek	***Seton-Anderson***	Moffat Creek	Marten Creek	Middle River	Birkenhead River
Porter Creek	Gates Channel	*Mitchell River*	Marten Lakeshore	Pinchi Creek	Green River
Takla Lake, NE Arm	Gates Creek	Cameron Creek	Roaring River	Sakeniche River	Harrison River
Ankwill Creek		Mitchell River	Roaring Lakeshore	Sowchea Creek	Poole Creek
Bates Creek	***South Thompson***	Penfold Creek	Sue Creek	Tachie River	Samson Creek
Blanchette Creek	Adams Channel	*Quesnel Lake, E Arm*	Trickle Creek		Weaver Channel
Forsythe Creek	Adams River, lower	Big Slide Lakeshore	Wasko Creek	***Nechako***	Weaver Creek
French Creek	Adams River, upper	Bill Miner Creek	Watt Creek	Stellako River	
Frypan Creek	Anstey River	Bill Miner Lakeshore	Watt Lakeshore		***Seton-Anderson***
Hudson's Bay Creek	Cayenne Creek	Blue Lead Creek	*Quesnel Lake, W Arm*		Portage Creek
Shale Creek	Celista Creek	Blue Lead Lakeshore	Hazeltine Creek		
Five Mile Creek	Eagle River	Bouldery Creek	Raft Creek		***South Thompson***
Ten Mile Creek	Hiuihill Creek	Bouldery Lakeshore	Spusks Lakeshore		Adams Lake
Fifteen Mile Creek	Hunakwa Creek	Bouldery Lakeshore, 2 km west			Adams River, lower
Twenty-five Mile Creek	Malakwa Creek	Killdog Creek			Adams River, upper
Takla Lake, NW Arm	McNomee Creek	Lynx Creek			Anstey River
Crow Creek	Momich River	Lynx Lakeshore			Bush Creek
Dust Creek	Nikwikwaia Creek	Niagara Creek			Canoe Creek
Hooker Creek	Onyx Creek	Slate Bay Lakeshore			Celista Creek
McDougall Creek	Perry River	Summit Creek			Eagle River
Point Creek	Ross Creek	Taku Creek			Hiuihill Creek
Sinta Creek	Salmon River	*Quesnel Lake, N Arm*			Hunakwa Creek
Takla Lake, Main Arm	Scotch Creek	Bear Beach Lakshore			Little River
Bivouac Creek	Seymour River	Betty Frank's Lakeshore			McNomee Creek
Gluske Creek	Yard Creek	Bowling Point Lakeshore			Momich River
Leo Creek		Deception Point Lakeshore			Nikwikwaia Creek
Narrows Creek	***North Thompson***	Devoe Creek			Pass Creek
Sakeniche River	Fennell Creek	Devoe Lakeshore			Perry River
Sandpoint Creek	Harper Creek	Goose Point Lakeshore			Salmon River
Middle River	Raft River				Scotch Creek
Forfar Creek					Seymour River
Kazchek Creek	***Chilcotin***				South Thompson River
Kynock Creek	Elkin Creek				Tappen Creek
Middle River	Taseko Lake				Yard Creek
Rossette Creek					*Shuswap Lake*
Trembleur Lake	***Nechako***				Anstey Arm
Felix Creek	Nadina Channel				Main Arm
Fleming Creek	Nadina River				Salmon Arm
Paula Creek					Seymour Arm
	Upper Fraser				*Shuswap River*
	Bowron River				Shuswap River, lower
	Indianpoint Creek				Shuswap River, middle
					Tsuius Creek
					Wap Creek

[a] Excludes streams with a record of intermittent escapements that were not surveyed in 1998.

Field Methods

The general objective of each study is to estimate the sex-specific escapement with a precision of within ±25%. This objective is addressed by applying tags to approximately 1% of the escapement, a level known from previous studies to provide the requisite precision, and by using techniques that distribute the tags proportionally across the population. Sockeye are normally captured immediately below the spawning grounds to ensure that the entire run is vulnerable while avoiding the disproportionate capture of local spawners. In some cases, however, the fish are captured at multiple sites on the spawning grounds; this occurs when river access is limited, or previous experience shows that the use of a single downstream site causes disproportionate tag distributions. Tagging begins when sockeye are first observed and continues through the entire period of spawning ground arrival. Daily tagging targets are determined either from abundance estimates based on the previous day's visual counts on or below the spawning grounds (*e.g.*, bridge counts or boat drifts) or by standardizing the application effort at a fixed number of net sets per day. Sockeye are captured using beach seine nets, marked with uniquely numbered, red Petersen disk tags, and released. They are released untagged when obviously stressed, at an advanced stage of maturation, or physically damaged. Date and location of capture, tag number, sex, nose-fork length, release condition and predator marks (lamprey, hook or net) and *Flexibacter columnaris* symptoms are recorded for each tagged fish. A second, blank disk tag is applied to all tagged sockeye to permit the estimation of tag loss. The tags are inserted through the dorsal fin's pterygiophore bones, with the numbered primary tag placed anterior to the blank secondary tag. Fish are not sampled for scales or otoliths during tagging; however, 50 females are retained for fecundity assessment.

Since 1995, the following fish handling procedures have been used to minimize stress: activity in the net is minimized to reduce siltation; fish are removed from the water only when a tagger is ready and processed as quickly as possible; when removed from the water, the fish are cradled in two hands rather than dangled by the caudal peduncle; and following tagging, the fish are immediately returned to the water. In 1998, concerns over incremental stress from migratory route conditions and the need to double tag all fish resulted in the following modifications: all fish were tagged either in a tray immersed in the water, or in an elevated tray with a built-in supply of running water; following tagging, the fish were carried in the water and released by depressing a section of the cork line; holding and processing time was limited to 90 minutes for sites with clean, well aerated water or 45 minutes for sites with low flow, sedimentation or high water temperatures; and holding time was recorded in 15 minute intervals. At no time in the process did the head of the fish leave the water for more than a few seconds.

The objective of the recovery survey is to recover carcasses in proportion to daily abundance. Crews survey the entire spawning area, beginning when the first dead sockeye are observed and continuing until the die-off is complete. Each survey is completed in a fixed period ranging from two to six days (depending on the study) to ensure that recovery effort is consistent through the run. This requires the frequent adjustment of the crew size, with more surveyors deployed at the peak of carcass abundance than at the tails of the abundance distribution. After enumeration, the tags are cut from the carcasses, and the carcasses are removed from the study area either by pitching them beyond the high water mark or by cutting them in two with a machete and returning them to the river. Periodic resurveys of previously processed carcasses are conducted to estimate the number of tags that are missed on the initial survey. Fresh carcasses are also sampled for length, otoliths and scales following a protocol provided by the Pacific Salmon Commission (PSC).

Previous analyses indicate that the precision objectives of Fraser River sockeye mark-recapture studies are generally exceeded by a considerable margin. Consequently, the 1998 recovery areas for the largest stocks were subsampled as a cost saving measure. Before the arrival of sockeye, each river was marked in 250 m (dense spawning areas) or 500 m (light spawning areas) subsections. Alternate subsections were surveyed and, within a subsection, only one, randomly selected bank was covered. This reduced the survey coverage by up to 75% without compromising its representativeness. Study-specific procedures are outlined below.

Adams Complex: The Adams complex is part of the South Thompson system in the southeast Fraser River watershed (Fig. 1). The study

population includes sockeye that spawn in the lower Adams River, Adams Lake and tributaries, Little River, Scotch Creek, and along the foreshores of Shuswap (west of the Scotch Creek mouth) and Little Shuswap lakes. Late Run sockeye first arrive on the spawning grounds in mid September. Peak spawning normally occurs in mid October, and the die-off is complete by late November.

Until 1994, tags were applied at a site on the Shuswap Lake foreshore adjacent to the Adams mouth. In 1994, the tagging site was moved into the Adams River to reduce the: a) capture probability of sockeye destined for other parts of the Shuswap Lake system; and b) catch per set, thereby making application more representative by increasing the daily number of sets, and reducing handling stress and immediate mortality by reducing holding time (Schubert and Fanos 1997a). In 1995, additional tagging sites were added in the middle and upper river to increase the tag rates in those areas (Houtman and Fanos 2000). Previously, the use of a single tagging site on the lake or in the lower river resulted in decreasing tag rates with distance upstream.

The 1998 study was conducted from September 21 to November 17. The study design was similar to that used in 1995 (Schubert 2007), except for changes described in the previous section and the following modifications: the tagging sites were shifted in response to channel changes; an additional site was established in Little River to increase the tag rate in the lower part of the study area; counting towers were erected at the mouth to provide the daily immigration estimates used to set tagging targets; and a radio-telemetry study, implemented on the recommendation of the FRSPRB (Anon. 1995b), documented intra-system movements to determine whether tagged sockeye reached the lower part of the study area through active migration or as a result of the flushing of carcasses. Tags were applied at six sites, one in the upper river, two each in the lower and middle rivers, and one in Little River. The daily tagging goals were set at 1% of the previous day's migration as estimated from the tower counts, and by standardized application effort in Little River. Recovery surveys were conducted on a two-day cycle, with subsampling of the Adams River and full coverage in other areas. Radio tags were applied in both the Adams and Little rivers and were monitored in the study area by fixed and mobile receivers.

Birkenhead River: The Birkenhead River, a tributary of Lillooet Lake, is part of the Harrison-Lillooet system in the southwest Fraser River watershed (Fig. 1). Late Run sockeye spawn primarily in the mainstem up to the canyon at km 28, and in a tributary, Poole Creek. They first arrive on the spawning grounds in mid August. Peak spawning normally occurs in late September, and the die-off is complete by early November.

The 1998 study was conducted from August 29 to October 19. The study design was similar to that used in 1994 (Schubert and Tadey 1997) and 1995 (Houtman *et al.* 2000), except for changes described in the previous section and the addition of two tagging sites. Tags were applied to migrating sockeye at three sites, one below the lower limit of spawning and two in the lower/middle river. Daily tag releases were established from standardized application effort, *i.e.* all fish from an equal number of sets were tagged each day. Complete recovery surveys were conducted on a 4-5 day cycle, *i.e.*, the entire spawning area was surveyed every 4-5 days.

Chilko System: The Chilko River is part of the Chilcotin River system in the west-central Fraser River watershed (Fig. 1). Summer Run sockeye spawn in the Chilko River downstream from the lake, in a spawning channel on the upper Chilko River, and along the foreshore of Chilko Lake. They first arrive on the spawning grounds in August. Peak spawning normally occurs in late September, and the die-off is complete by late October.

Until 1987, the Chilko study was designed to estimate the escapement of the river population only; the lake populations were estimated using a variety of subjective techniques. In 1987, the study was changed to the current design that provides a system-wide (river, spawning channel and north and south lake) estimate of escapement. In 1987-1989, migrating fish were tagged near the confluence of the Chilko and Taseko rivers (Fig. 1); in 1990, the tagging site was moved upstream to the current site at Lingfield Creek near the lower limit of spawning.

The 1998 study was conducted from August 14 to October 19 in the upper Chilko River and Chilko Lake. The study design was similar to that used in 1994 (Schubert and Fanos 1997b) except for the changes described in the previous section and the following modifications: the extent and frequency of the south lake surveys were increased, and the surveys started earlier; the river between Lava Canyon and Lingfield Creek was surveyed to improve the assessment of immediate mortality; and the spawning channel was included in the study area, and was opened to permit spawners destined for the upper part of the study area to migrate back into the river. Tags were applied to migrating sockeye at Lingfield Creek, with daily tagging goals set at 1% of the previous day's migration as estimated from visual counts at Henry's Bridge (4 km below the tagging site). Recovery surveys were conducted on a cycle of 3-4 days in the river, 4-5 days in the north lake, and weekly in the south lake. Complete recovery surveys were conducted in the river and north lake; in the south lake, foot surveys were restricted to known spawning areas and the remainder of the area was surveyed by boat.

Eagle River: The Eagle River, a tributary of the Salmon Arm of Shuswap Lake, is part of the South Thompson system in the southeast Fraser River watershed (Fig. 1). Early Summer Run sockeye spawn in the mainstem and in two tributaries, Perry River and Yard Creek. They first arrive on the spawning grounds in August. Peak spawning normally occurs in early September, and the die-off is complete by late November.

Previously, visual surveys were used to assess the Eagle River sockeye escapement. Such surveys are effective in the clear water above the Perry River confluence, which traditionally supported the bulk of the escapement, but ineffective in the silty water discharged into the lower river by Perry River. In 1994, the escapement was unusually large (45,000) and spawned primarily in the turbid lower river. Because visual surveys are poorly suited to such large abundances and limited visibilities, the escapement was likely underestimated. Consequently, on the recommendation of the FRSPRB (Anon. 1995b), a mark-recapture study was implemented for the first time in 1998. The 1998 study was conducted from August 20 to September 20. Tags were applied to migrating sockeye near the lower limit of spawning, with daily tag releases established from standardized application effort; however, the tagging site proved relatively ineffective, and the beach seining operation was later moved to the spawning grounds. Complete recovery surveys were conducted on a four-day cycle.

Horsefly River: The Horsefly River, a tributary of the main section of Quesnel Lake, is part of the Quesnel River system in the east-central Fraser River watershed (Fig. 1). The Horsefly is a group of Summer Run stocks that spawn in the lower and upper Horsefly and Little Horsefly rivers, in McKinley and Moffat creeks, and in a spawning channel on the Horsefly River 25 km above Quesnel Lake. Sockeye first arrive on the spawning grounds in August. Peak spawning normally occurs in early to mid September, and the die-off is complete by mid October.

The 1998 study was conducted from August 17 to October 7. The study design was similar to that used in 1994 (Cone 1999) and 1995 (Houtman and Cone 2000) except for the changes described in the previous section and the exclusion from the study area of the low gradient area between the lower and upper spawning grounds. The study had four components. First, tags were applied to migrating sockeye in the lower river approximately 2 km above the lake; daily tag releases were established from standardized application effort. Recovery surveys were conducted in the lower and upper river on a four-day cycle, with subsampling on the Horsefly River and full coverage in other areas. Second, the spawning channel was enumerated by a complete carcass count. Third, McKinley Creek was enumerated at a fence located near the confluence with the Horsefly River. This permitted a full enumeration (and removal from the mark-recapture data set) of tagged sockeye that emigrated from the Horsefly study area. Fourth, the populations in the Little Horsefly River, Moffat Creek and tributaries to Quesnel Lake were surveyed on foot using the procedures described later.

Little River: The Little River is a short interlake system that flows between Shuswap and Little Shuswap lakes in the South Thompson system in the south-central Fraser River watershed (Fig. 1). Late Run sockeye spawn through-

out the river. They arrive on the spawning grounds in late September. Peak spawning normally occurs by late October, and die-off is complete by late November.

Previous dominant cycle escapements in Little River have been assessed as part of the Adams complex; the Little River population's contribution to the complex was estimated from visual surveys. Concerns expressed by the FRSPRB (Anon. 1995b) led to a redesign of the study in 1998. An independent mark-recapture study was designed to generate a discrete population estimate for Little River sockeye while, at the same time, a radio-telemetry study was implemented to establish whether an independent estimate was actually required. A new tagging site was established in Little River; daily beach seining effort was standardized, and spawning rather than migrating sockeye were selected for tagging. When it became apparent from the tagging and radio-telemetry studies that Little River sockeye were a component of the larger Adams complex, the new tagging site was incorporated into the Adams study. The Little River data were also analysed separately to produce a discrete estimate for that population.

Middle River: The Stuart River system is located in north-central British Columbia and constitutes the most northern portion of the Fraser River watershed (Fig. 1). Summer Run sockeye, commonly termed the late Stuart stock, spawn in the Tachie and Middle rivers and in streams tributary to Stuart Lake (Pinchi and Sowchea creeks), Tachie River (Kuzkwa River), Middle River (Kazchek Creek) and Takla Lake (Sakenichie River). They first arrive on the spawning grounds in late August, with peak spawning normally occurring in late September; the die-off is complete by mid-October.

The Middle River flows between Takla and Trembleur lakes in the northern part of the Stuart River watershed. Previously, the subdominant cycle escapement was estimated from visual surveys conducted by air and foot during the peak of die-off. The first mark-recapture study on this cycle was conducted in 1994 after escapements exceeded the threshold for intensive assessment. The 1998 study was conducted from September 9 to October 15. The study design was similar to that used in 1994 (Schubert and Fanos 1997c) except for the changes described in the previous section and the relocation of tagging to two sites in the lower river near Kazchek Bar. Daily tag releases were established from standardized application effort. Recovery surveys were conducted on a 3-4 day cycle in the main riverine spawning areas; the lake-like portions of the river were excluded because spawning density was light.

Mitchell River: The Mitchell River is a tributary of the North Arm of Quesnel Lake in the east-central Fraser River watershed (Fig. 1). Summer Run sockeye spawn in the mainstem and in two tributaries, Cameron and Penfold creeks. They arrive on the spawning grounds in August. Peak spawning normally occurs in mid September, and die-off is complete by mid October.

The 1998 study was conducted from August 27 to October 8. The study design was similar to that used in 1994 (Schubert 1997a). Design changes are described in the previous section. Concerted efforts were made to improve on the poor execution of the study design that occurred in 1994. Tags were applied to migrating fish at one site near the lower limit of spawning, with the daily release based on standardized application effort. Complete recovery surveys were conducted on a 4-5 day cycle in the main spawning area, and weekly in the upper river where the abundant grizzly bear population prevented frequent access.

Pitt River, upper: The Pitt River is a tributary of the Fraser River in the southwest portion of the Fraser River watershed (Fig. 1). Early Summer Run sockeye spawn primarily in the lower 17 km of the mainstem of the upper Pitt River (*i.e.*, above Pitt Lake) and in three tributaries, Boise, Corbold and Fish Hatchery creeks. They arrive on the spawning grounds in early August. Peak spawning normally occurs in mid September, and die-off is complete by late September.

Previously, escapements were estimated from tags applied during hatchery brood stock acquisition and later recovered during often *ad hoc* surveys of the spawning grounds. Because the primary focus of field activities was not population estimation, the results did not provide de-

fensible population estimates. The 1998 study, conducted from July 29 to October 1, was the first upper Pitt River study explicitly designed to provide defensible escapement estimates. Tags were applied to migrating sockeye at a site near the lower limit of spawning, with daily tag releases established from standardized application effort, and from test sets in Corbold Creek to monitor tag rates. Complete recovery surveys were conducted on a four-day cycle.

Seymour River: The Seymour River, a tributary of the Seymour Arm of Shuswap Lake, is part of the South Thompson River system which drains a large portion of the southeast Fraser River watershed (Fig. 1). Early Summer Run sockeye spawn in the river and its main tributary, McNomee Creek. They arrive on the spawning grounds in August. Peak spawning normally occurs in early September, and die-off is complete by late September.

The 1998 study was conducted from August 22 to September 21. The study design was similar to that used in 1994 (Schubert 1997b) and 1995 (R. Houtman, pers. comm..) except for the changes described in the previous section. Tags were applied to migrating sockeye at a site near the lower limit of spawning, with daily tag releases established from standardized application effort. Complete recovery surveys were conducted on a four day cycle. McNomee Creek was surveyed on foot using the visual survey procedures described later.

Shuswap System: The Shuswap River, a tributary of Shuswap Lake, is part of the South Thompson system in the south-east Fraser River watershed (Fig. 1). The system consists of the upper, middle, and lower Shuswap Rivers, delineated by Sugar, Mabel, and Mara lakes, respecttively, and a number of small tributaries. Late Run sockeye spawn in the lower and middle rivers, and in three Mabel Lake tributaries, Noisey, Tsuius, and Wap creeks. They first arrive on the spawning grounds in late September. Peak spawning normally occurs in mid October, and the die-off is complete by mid November.

The 1998 study was conducted from September 28 to November 2. The study design was similar to that used in 1994 (Schubert and Vivian 1997) except for the changes described in the previous section and the following study-specific modifications: both application and recovery surveys were made spatially and temporally representative (a serious 1994 design deficiency), with the middle and lower rivers surveyed at the same frequency; and a second tagging site was added in the lower river near Mabel Lake. The latter was intended to increase the tag rate in the middle river; however, the site was dropped from the analysis when it became apparent that most of the fish tagged at this site spawned in the lower river. Tags were applied to migrating sockeye at the main tagging site near the lower limit of spawning. Complete recovery surveys were conducted on a four-day cycle. The Mabel Lake tributaries were surveyed on foot using the visual survey procedures described later.

Tachie River: The Tachie River, part of the Stuart River system, flows between Trembleur and Stuart lakes (Fig. 1). Summer Run sockeye spawn in the upper portions of the Tachie River and in the main tributary, Kuzkwa River. They first arrive on the spawning grounds in late August, with peak spawning normally occurring by late September; the die-off is complete by mid-October.

The 1998 study was conducted from September 4 to October 16. The study design was similar to that of the first mark-recapture study conducted on this cycle in 1994 (Schubert and Fanos 1997c). Design changes include those described in the previous section, as well as the following study-specific actions: additional tagging sites were established in the upper river to improve tag distributions; and the Kuzkwa River stock was enumerated at a fence located near the confluence with Tachie River. The latter permitted a full enumeration (and removal from the mark-recapture data set) of tagged sockeye that emigrated from the Tachie study area. Tags were applied at four sites in the upper river, two near Kuzkwa Bar and two lower in the spawning area. Complete recovery surveys were conducted on a three-day cycle.

Weaver Creek: Weaver Creek, a tributary of the Harrison River, is part of the Harrison-Lillooet system in the southwest Fraser River watershed (Fig. 1). The Weaver is a short creek with a total accessible length of only 4.8 km. A spawning channel enters the creek at km 0.8,

where a barrier weir divides the creek into upper and lower sections. Late Run sockeye spawn in the lower creek; passage into the channel and upper creek is controlled by channel staff. Sockeye arrive in the creek in late September. Peak spawning normally occurs in late October, and the die-off is complete by mid November.

Assessment of Weaver sockeye is complicated by the return of large numbers of channel-produced fish that are surplus to spawning requirements. The 1998 terminal return had five components: sockeye harvested by the Chehalis Indian Band in the Harrison River near Weaver Creek; lower creek spawners; channel spawners; sockeye that returned to the channel but were surplus to channel requirements; and spawners passed over the weir into the upper creek. The surplus and channel returns were censused, and the upper creek fish were enumerated over the weir. The study was designed, therefore, to estimate the lower creek spawners.

The 1998 study was conducted from October 10 to November 2. Tags were applied to local spawners at a number of sites in the lower creek, with daily tagging targets based on observed spawner abundance. Complete recovery surveys were conducted on a two-day cycle in both the lower and upper creeks. Because channel staff passed carcasses that accumulated on the weir into the lower creek rather than remove them from the system, it was necessary to expand the study area to include the upper creek.

Analytic Procedures

The analytic process involves four steps. First, data are entered into a computer database and their veracity verified. Second, the data are evaluated and corrected for (in order) sex identification error, emigration from the study area, missed tags, tag loss and acute stress effects. Third, population estimates are calculated for adult males, females and precocious males (if five or more tags are recovered). Fourth, a bias and stress profile is developed by evaluating four potential biases (temporal, spatial, fish size and sex) and six potential indicators of stress (incidence of *F. columnaris* infections, condition at release, recovery effects of additional stresses such as long holding time or multiple recapture, elapsed time to recovery, recovery distribution and spawning success). This profile is used to subjectively evaluate overall bias for each population. The first step is self-explanatory; the latter three steps are described in more detail below.

Data Corrections: Before calculating population estimates, we evaluate (and correct when appropriate) the data in four ways. First, sex identification errors at tagging can result from the limited development of sexually dimorphic traits among newly arriving spawners (live fish cannot be examined internally) or simply from recording errors during the sometimes hectic tagging operation. We correct such errors by comparing the sex of tagged fish recorded at release and recovery, and applying the procedures described by Staley (1990). It is unnecessary to correct the carcass recovery data because the carcasses are examined carefully and can be incised for internal examination. Second, tagged sockeye sometimes spawn outside the study area. Their number is estimated from area-specific estimates of tag incidence and population size provided from assessments independent of the mark-recapture study; the sex-specific estimate is subtracted from the application sample. Third, the failure to correctly identify tagged carcasses can occur as a result of surveyor inexperience, fatigue, or carelessness. Resurvey data are used to estimate the incidence of missed tags and to correct the recovery data. Fourth, fish can lose tags between application and recovery for a number of reasons. We use the double tags to estimate the tag loss rate for primary and secondary tags; the product of the rates is an estimate of the simultaneous rate of loss of both tags. These data are used to correct the recovery sample for tag loss.

Population Estimation: In this section, we briefly describe estimation procedures for adults, precocious males (hereafter, *jacks*), and females that spawned effectively (hereafter, *effective females*). For adults, we use the Stratified Population Analysis System (SPAS) software developed by Arnason *et al.* (1996) to calculate sex-specific population estimates (the use of sex-specific data avoids potential biases resulting from differences in arrival timing and behaviour on the spawning grounds). SPAS calculates estimates and standard errors using the pooled Petersen estimator (PPE) (Seber 1982) and the stratified Darroch maximum likelihood estimator (MLE) (Plante 1990). The latter is generated from application-recovery matrices using temporal:temporal (TxT), temporal:spatial (TxS) and spatial:spatial (SxS; where appropriate) stratifications. Temporally, we

stratify the data into 4-6 application and recovery periods in which the number of tags applied or recovered are approximately equal. Spatially, we use 2-5 application (multiple tag site studies) and recovery strata. Pooling is often required to satisfy the assumptions of model fit, *i.e.*, to minimize the number of low recovery cells and reduce linear dependence in the recovery matrix.

Formerly, Fraser mark-recapture studies evaluated sampling selectivity to determine whether to use the PPE or MLE. The PPE was used when selectivity tests showed no evidence of bias. When bias was detected, the MLE was used only if the 95% confidence limits of the PPE and MLE did not overlap (the bias was judged to be minor if the 95% confidence limits overlapped). In 1998, we abandon the MLE in favour of the PPE for two reasons. First, the MLE appears reliable only when there is a strong temporal correlation between application and recovery strata. Such correlations are typically observed only when tagging and recovery occur on an active migratory route where there is a largely contagious migration between the sites (*e.g.*, Schwarz and Taylor 1998); they are not characteristic of most sockeye studies, where mixing across strata is common. Second, there are no clear rules for choosing among the MLE estimates calculated under different stratifications. The experimenter can be faced with a large number of valid estimates, but no way to identify those that improve on the accuracy of the PPE (*e.g.*, Schubert 2000). Consequently, we reject the MLE for population estimation but retain it for bias evaluation (described later). Even in bias evaluation, however, we advise caution in interpreting MLE results.

The jack escapement is similarly calculated when five or more tags are recovered. This did not occur in 1998; consequently, an alternate population estimator is used. The jack escapement is estimated as the product of the number of carcasses recovered, an expansion factor (1.26) developed by the IPSFC, and the inverse of the 1998 study-specific mark recovery rate for adult males. The expansion factor is based on comparisons of jack and adult male recovery rates from previous mark-recapture studies (Andrew and Webb 1987). The source data for these comparisons, however, are not documented in published reports and have not been provided to DFO in unpublished form. A review of this estimation procedure recommended by Schubert (1998) has not been completed.

The effective female population is the product of the female escapement estimate and the average spawning success. The latter is calculated from the female carcass recovery sample; daily results are weighted to the number of female carcasses recovered that day because egg retention is not recorded for all carcasses.

Sampling Selectivity Assessment: The assumptions of equal probability of capture, simple random recovery sampling and complete mixing (Seber 1982, p 434-9) are assessed by testing the application and recovery samples for temporal, spatial and sex biases using chi-square tests, and size bias using the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf 1981). We assess application bias (unequal probability of capture or incomplete mixing) by stratifying the recovery sample and comparing the proportion tagged among strata. Recovery bias (non-random recovery sampling or incomplete mixing) is assessed by stratifying the application sample and comparing the proportions recovered. These assessments are presented for each study, and are compared to similar tests from the 1995-1997 studies.

Temporally, we stratify the application and recovery samples into 5-6 periods of approximately equal duration, sampling effort, and sample size (*i.e.*, three stratifications each). We interpret three significant results to be a true bias, while a single significant result may be a stratification artifact. Spatially, we stratify the application sample based on the number of tagging sites, and aggregate the recovery sample into 3-6 geographically contiguous sections. Sex bias at application is assessed by comparing the sex ratios of marked and unmarked recoveries. Recovery bias is assessed by comparing the sex ratios of tagged fish that are recovered and those that are not. We examine size bias at recovery (application bias cannot be assessed because unmarked carcasses are not measured) by comparing the cumulative NF length-frequency distributions of recovered and non-recovered portions of the application sample.

Stress Assessment: A critical assumption of mark-recapture studies is that marked and unmarked animals have the same probability of recapture (*i.e.*, recovery); if this assumption is not met, the population estimate will be biased. If the stress of marking (capture and holding in the net, handling during tagging and release) causes tagged sockeye to behave differently

than untagged fish (*e.g.*, spawning distribution, timing of die-off), this can result in differential probabilities of recapture. In 1998, sockeye were handled in a low-stress manner. If, however, their fitness upon return to the spawning grounds was poorer than normal due to *en route* conditions, tagging stress could represent the 'last straw' and lead to altered behaviours for a larger than normal proportion of the tagged fish.

To determine whether returning sockeye were in poor condition, we evaluate four variables that are likely correlated with condition (*i.e.* condition indicators) and compare the results with those for 1994-1997. First, some sockeye require ventilation after tagging. If the fish are already stressed before capture, the proportion requiring ventilation will likely be higher (although small difference can be ignored because the evaluation is subjective). Second, some marked sockeye are recaptured in the seine net used at the tagging site. This fraction may be larger if sockeye are in poor condition because healthy fish are more likely to resume their migration and clear the tagging site quickly (this comparison is valid only when similar tagging sites are used each year). Third, sockeye in poor condition may die sooner, reducing the time between tagging and recovery. Fourth, the mean spawning success of females (the fraction of eggs deposited) is likely to be correlated with fish condition because females in poor condition are likely to die before spawning completely. A fifth condition indicator, the incidence of *Flexibacter columnaris* lesions, was considered and rejected because such observations were not recorded in all studies across all years.

To determine whether capture and handling stress may have represented the last straw by altering the behaviour and recovery probability of tagged sockeye, we evaluate four indicators across 1994-1998. First, we compare recovery rates of fish that required ventilation at release (assumed to be a symptom of arrival stress) and those that did not. Second, we similarly compare recovery rates of fish recaptured at the tagging site. Third, we compare the fractions among tagged and untagged females that had completely spawned. Fourth, we examine the influence of tag status on the recovery distribution of carcasses. The latter two comparisons are stronger indicators of the effect of tagging stress on recovery rates because they compare aspects of the behaviour of tagged and untagged sockeye. We additionally compare recovery rates among releases stratified in 15-minute increments of holding time. Similar data are unavailable in previous years; therefore, multi-year comparisons are not made.

Bias Assessment: We cannot definitively evaluate the accuracy of the mark-recapture estimates because the true population size is unknown. Instead, we rely on three somewhat limited assessments to provide a largely subjective evaluation of the potential magnitude and direction of the bias.

First, on a relatively gross and subjective level, we evaluate how well the study design was executed. Did tagging begin when sockeye first arrived and continue until the migration was complete? Did recovery begin shortly after the start of tagging, cover the entire study area, and continue until the die-off was complete? Were the tagging and recovery efforts applied representatively over time and space? Were lost and missed tags reliably assessed? If the answer to these questions is yes, then the study design was adequately executed and the estimates can reasonably approximate the true population size.

Second, on a more refined but still subjective level, we evaluate complementary stratifications of the two-sample data (*e.g.*, recovery rate by application period versus tag incidence by recovery area) to determine if the observed biases also bias the population estimate. This level of evaluation can likely provide a reasonable approximation of the probable direction and relative magnitude (on a gross scale) of estimation bias. This analysis focuses on an evaluation of the probabilities of tagging (P_{cap}) and recovery (P_{rec}); if correlated, the PPE estimate will be biased. Such correlations exist if P_{cap} and P_{rec} are both dependent on correlated variables. While several mechanisms can lead to this relationship, three are especially likely in sockeye mark-recapture studies: for multiple tagging site studies, spatial (hereafter, *SxS*) dependencies can result when the physical characteristics of a given section of river make P_{cap} and P_{rec} anomalous, and fish tagged in the area also spawn locally; temporal (*TxT*) dependencies can occur because time of arrival and time of death are usually correlated; and temporal:spatial (*TxS*) dependencies can result when P_{cap} varies temporally and P_{rec} varies spatially because arrival time can be correlated with spawning (and recovery) area (*e.g.*, early arriving sockeye migrate faster and spawn in the upper river, while the reverse

true of late migrants). To evaluate the influence of each of these mechanisms, we graph tag incidence versus recovery time and area to illustrate temporal and spatial patterns in P_{cap}. Similarly, we graph recovery rate versus application time and tagging site to illustrate temporal and spatial patterns in P_{rec}. To evaluate the influence of the *TxT* mechanism, the two temporal trends are compared. Similarly, to evaluate the influence of the *SxS* mechanism, the two spatial trends are compared. Finally, in cases where there appears to be a correlation between tagging date and recovery area, the temporal trend in tag incidence and the spatial trend in recovery probability are compared to evaluate the influence of the *TxS* mechanism.

Third, on a more quantitative level, Schwarz and Taylor (1998) suggest that comparing the MLE and PPE estimates provides an estimate of PPE bias. We reject this as a reliable quantitative approach for the reasons noted previously (see *Population Estimation*). Instead, we compare the MLE and PPE to roughly estimate the maximum probable PPE bias. We generate at least three valid MLE estimates (those with acceptable Plante's G^2 and χ^2 test results) from three matrices, TxT, TxS, and SxS. Because there are no criteria to select among the alternate estimates, we report the largest MLE-PPE discrepancy, and the fraction of the valid MLE estimates that are larger than the PPE estimate.

ENUMERATION FENCE STUDIES

This section describes: a) enumeration fences, *i.e.*, structures to intercept and permit the enumeration of sockeye as they migrate into a spawning area; and b) spawning channels, that have control structures to permit complete live counts and the enumeration of carcasses. In both cases, it is possible to obtain an almost complete census of the spawner population.

In 1998, enumeration fences were used for 11 stocks: Forfar, Gluske and Kynock creeks on the Early Run; Gates and Scotch creeks on the Early Summer Run; Kuzkwa and Stellako rivers and McKinley Creek on the Summer Run; and Salmon River, and Sweltzer and Weaver creeks on the Late Run. Fences were installed on two additional streams supporting Late Run stocks, Nikwikwaia Creek and Momich River. They were primarily intended to assess coho salmon escapements and, either spatially or temporally, did not assess the entire sockeye return; consequently, they are not used to estimate escapement. Project objectives vary among the enumraion fence studies. The fences on Early Run Stuart stocks provide inseason calibrations for the visual surveys conducted in the area. The Kuzkwa and MacKinley fences both enumerate large stocks, and permit the removal of tagged sockeye from the mark-recapture data sets for the Tachie and Horsefly populations, respectively. The Stellako fence provides a harvest platform for native fishers and permits the evaluation of bias in a major mark-recapture study. The remaining fences are operated by other agencies within or external to DFO.

Six spawning channels operated in 1998: Gates and Nadina on the Early Summer Run; Chilko and Horsefly on the Summer Run; and Weaver and Adams on the Late Run. Channel counts are used to estimate escapement in all but the Adams and Chilko channels, where escapement is estimated as part of the respective mark-recapture study.

Field Methods

The fences operate continuously through virtually the entire migration. After a fence is installed, visual surveys are conducted to estimate the number of sockeye already in the river. The fence then funnels the remainder of the run into a counting area where the fish are either intercepted for sampling or tagging, or counted as they swim over a white board installed in an opening in the fence. Data collected at the fence include species-specific daily counts of adults, jacks and disk tagged fish (if part of a mark-recapture study). Sex is not recorded because it cannot be reliably determined in moving sockeye; however, sex ratios and female spawning success are estimated from regular surveys above the fence. If spawning occurs below the fence, regular foot surveys are conducted using the visual survey techniques described later.

Live sockeye are counted as they enter the spawning channels, and all carcasses are counted and removed from the channels after the die-off begins. Escapement is estimated from the carcass count, when complete, or from the count of live sockeye entering the channel.

Analytic Procedures

For the Gates, Kuzkwa, MacKinley, Sweltzer and Weaver populations, the channel or fence

counts provide a census of the escapement. If the fence is installed after some spawners arrive (Stellako River), or if spawning occurs below the fence (Forfar, Gluske and Kynoch creeks), the estimated escapement is the sum of the upriver live count on the date of fence installation, the fence count, and the below-fence estimate. The latter is calculated using techniques described later (see *Visual Surveys*). The sex composition and female spawning success are estimated from the associated carcass survey data. Fecundity is sampled at most fences and carcasses are sampled according to the protocols provided by the PSC.

Bias Assessment: Estimation accuracy depends on the proportion of the stock that is actually enumerated. This is determined by how well the study design is implemented: Was the fence installed after the arrival of sockeye? Were operations interrupted during the migration? Was the fence removed before the migration was complete? Did it inhibit immigration, causing sockeye to hold or die downstream? Did large daily abundances confound the counts? If the answer to these questions is yes, then a higher proportion of the escapement is estimated rather than counted and accuracy is reduced.

VISUAL SURVEYS

Visual surveys are used for stocks with expected escapements of less than 25,000 spawners; this includes both the typically small stocks and the major stocks on an off-cycle year. The majority of the stocks were surveyed visually in 1998; specifically: all 38 from the Early Run; 26 from the Early Summer Run; 49 from the Summer Run; and 35 from the Late Run.

Field Methods

Spawning streams and lakes are inspected visually by an experienced observer. Survey periods are based on historic averages or, if one stream in an aggregate is surveyed more intensively, a peak in that stream triggers the survey of nearby streams. Each survey covers the entire accessible spawning area using one or more techniques that include foot or boat surveys and aerial overflights. The actual technique used for a given stock is determined largely by the physical features of each lake, river, or stream. Surveys are scheduled during the daily period of optimal light conditions, when possible, to minimize surface glare. Each stock is surveyed at least once, with some stocks visited a dozen or more times based on the expected escapement and the observations on the initial surveys. The following information is recorded on each trip: counts of live and dead sockeye; viewing conditions; water level and temperature; and conditions that might influence spawning success (*e.g.*, beaver dams, habitat encroachments). For the foot and boat surveys, all carcasses are recorded by date, location, sex and female spawning success; sex and spawning success can not be recorded during aerial surveys. After enumeration, the carcasses are removed from the study area by pitching them beyond the river's mean high water mark or by cutting them in two and returning them to the water.

Analytic Procedures

Escapement is estimated using the IPSFC procedures (Andrew and Webb 1987). For lake spawning populations where water depth or turbidity preclude the direct observation of live fish, estimated escapement is the product of the total number of carcasses recovered and an effort expansion that assumes each person-day of survey effort recovers 5% of the population. For river and lake spawning stocks where conditions permit the observation of live spawners, the total escapement is the product of the maximum daily count of live spawners, the cumulative recovery of all carcasses (males, females, jacks) through the date of the peak live count, and an index expansion factor. Two index expansion factors are used: a) the escapement of most stocks is calculated using a factor of 1.8. Both this index expansion factor and the effort expansion factor identified above are based on historic comparesons of visual survey and mark-recapture or fence data (Woodey 1984). The source data for these comparisons, however, are not documented in published reports and are available to DFO only in unpublished form; a review suggested by Schubert (1998) has not been completed; and b) the escapement of the Early Run in the Stuart system is calculated using the index expansion factor measured annually at three enumeration fences in the Middle River area.

The total escapement is partitioned into adult males, females and jacks in three steps. First, the total carcass recovery (rather than the cumulative recovery to the date of the peak live count) is adjusted in two ways: a) unsexed carcasses are excluded; and b) an expansion factor of 1.26

Table 3. Dates of start and completion of tagging and recovery, first sighting of sockeye, and of peak live and dead counts, and proportions of carcasses recovered on the peak and final recovery cycles, in the 1998 Fraser River sockeye salmon mark-recapture studies.

	Tag application		Carcass recovery		First sockeye seen				% of recoveries	
Study	Start	End	Start	End	Date	N	Peak of spawning	Dates of peak recovery cycle	Peak cycle	Final cycle
Adams	21-Sep	3-Nov	23-Sep	17-Nov	14-Sep	28	Oct 18-25	Oct 24-25	10.8%	0.7%
Birkenhead	29-Aug	27-Sep	11-Sep	19-Oct	29-Aug	50 [a]	Sep 22-27	Sep 30 - Oct 4	31.6%	3.3%
Chilko	14-Aug	30-Sep	21-Aug	19-Oct	1-Aug	4	Sep 25 - Oct 5	Sep 30 - Oct 2	15.2%	8.5%
Eagle	20-Aug	10-Sep	25-Aug	20-Sep	17-Aug	1	Sep 5-10	Sep 10-12	27.8%	6.7%
Horsefly	17-Aug	20-Sep	21-Aug	7-Oct	15-Aug	6	Sep 7-17	Sep 14-17	24.8%	2.3%
Middle	9-Sep	27-Sep	22-Sep	15-Oct	9-Sep	26 [a]	Sep 26 - Oct 5	Oct 1-3	32.6%	4.6%
Mitchell	27-Aug	18-Sep	3-Sep	8-Oct	26-Aug	4,050	Sep 18-25	Sep 22-26	34.9%	1.3%
Pitt	29-Jul	11-Sep	2-Aug	1-Oct	29-Jul	13 [a]	Sep 15-20	Sep 22-26	32.6%	17.6%
Seymour	22-Aug	12-Sep	16-Aug	21-Sep	19-Aug	9	Sep 6-8	Sep 13-15	25.6%	8.7%
Shuswap	28-Sep	19-Oct	2-Oct	2-Nov	26-Sep	235	Oct 12-16	Oct 18-21	32.2%	5.5%
Tachie	4-Sep	27-Sep	23-Sep	16-Oct	4-Sep	3 [a]	Sep 26 - Oct 2	Oct 2-4	25.0%	3.9%
Weaver	10-Oct	29-Oct	8-Oct	2-Nov	10-Oct	25 [a]	Oct 11-16	Oct 24	15.9%	5.8%

[a] Number of sockeye tagged on the first day of tag application.

is applied to the total jack recovery. The ratio of adult males, females and jacks from these adjusted data is then used to calculate the escapement of adult males, females and jacks. Second, if the adult carcass recovery (excluding unsexed carcasses and jacks) is greater than or equal to 10% of the estimated escapement, then the estimate is stratified by adult males, females and jacks on the basis of the proportions calculated above. Third, if the total adult carcass recovery is less than 10% of the escapement estimate, then the sex and jack composition and female spawning success is estimated from a nearby stock or stock aggregate with a similar run timing (jacks are excluded from this calculation if none were recovered by the survey of the stream in question). If a similar nearby stock is unavailable, then the total escapement is allocated equally between sexes and spawning success is assumed to be 100%.

Carcass samples are obtained for stocks specified by the PSC protocol; fecundity samples are not obtained from these smaller stocks.

Bias Assessment: Estimation accuracy depends on the study design, how appropriate it is to the population size, and how well it is executed. We evaluate it in a largely subjective manner by considering the following criteria: a) estimated population size (<25,000); b) calibration technique (inseason or historic average); c) survey frequency; d) survey coverage (partial or complete); and e) survey conditions (visibility of fish).

RESULTS AND DISCUSSION

MARK-RECAPTURE

The 13 stocks assessed using mark-recapture studies are identified in Appendix 11. These stocks account for 87% of the 1998 Fraser River sockeye escapement estimate, 1,779,200 males, 2,075,900 females and 3,700 jacks. The attributes of these estimates are described below.

Implementation Of Study Design

In this section, we address the following questions. Did tagging begin when sockeye first arrived and continue until the migration was complete? Did recovery begin shortly after the start of tagging, cover the entire study area, and continue until the die-off was complete? Was the tagging and recovery effort applied representatively over time and space? Were lost and missed tags reliably assessed? Were study precision objectives achieved?

Tagging: Tagging generally began within three days of the arrival of the first sockeye (Table 3). In the Chilko study, tagging began when more

Table 4. Percent of the escapement tagged and recovered, of the carcasses resurveyed, and of tags missed on the inititial survey in the 1998 Fraser River sockeye salmon mark-recapture studies.

	% of population tagged			% of population recovered			Percent of population resurveyed	Percent of tags missed
Study	Males	Females	Total	Males	Females	Total		
Adams	1.1%	0.9%	1.0%	15.8%	14.6%	15.2%	70.7%	2.7%
Birkenhead	1.1%	0.9%	1.0%	33.4%	25.8%	28.7%	32.5%	3.6%
Chilko	0.8%	0.8%	0.8%	24.4%	22.0%	23.0%	44.2%	1.3%
Eagle	0.6%	0.4%	0.5%	14.9%	14.6%	14.7%	29.8%	0.0%
Horsefly	1.3%	1.2%	1.2%	12.1%	11.5%	11.8%	53.4%	2.7%
Middle	1.5%	1.5%	1.5%	23.2%	25.4%	24.3%	39.4%	0.0%
Mitchell	1.2%	1.0%	1.1%	13.2%	11.9%	12.5%	37.4%	3.2%
Pitt	1.3%	1.1%	1.2%	10.1%	9.0%	9.4%	80.7%	0.0%
Seymour	2.4%	2.9%	2.6%	11.2%	15.9%	13.3%	15.2%	0.0%
Shuswap	1.1%	0.9%	1.0%	21.7%	20.4%	21.1%	77.5%	1.4%
Tachie	0.7%	0.9%	0.8%	13.2%	15.7%	14.4%	10.4%	0.0%
Weaver	2.8%	2.9%	2.8%	54.6%	42.3%	48.2%	46.4%	0.0%
Mean:	1.3%	1.3%	1.3%	20.7%	19.1%	19.7%	44.8%	1.2%

than ten sockeye per index period were observed from Henry's Bridge (5 km downstream of the tagging site) (Appendix 6). The few fish seen two weeks before the start of tagging (Table 3) represent a small number of immigrants that arrived very early relative to the bulk of the stock. The Adams study began seven days after sockeye were first seen, a result of the extremely early migration of Late Run South Thompson sockeye. The Mitchell study also began late, as indicated by the live count of 4,050 on the first day after crews arrived (Table 3). The tag incidence among early recoveries (discussed below) was higher than average in both the Adams and Mitchell studies, however, indicating that the delays did not affect the temporal distribution of the tags. Tagging always continued until it was difficult to capture fresh sockeye, indicating the near completion of the immigration.

Carcass Surveys: Surveys near the tagging area and spot checks in other areas began the day after the start of tagging. Regular recovery surveys began after carcasses were first observed. This occurred within one week of the start of tagging in all studies except the Birkenhead (13 days), Middle (13 days) and Tachie (19 days) (Table 3). In all studies, recovery surveys continued at least ten days after the end of the spawning peak, and until no new spawners were observed. In all studies except the Pitt, the carcasses recovered on the final cycle represent less than 10% of the total recovery. In all studies, less than 35% of the carcasses were recovered on the peak recovery cycle (Table 3). The recovery rates of tagged sockeye decreased near the end of the project in the Chilko and especially the Pitt studies; the potential impact on the population estimates is discussed below. Previously documented distributions of spawning and carcasses were used to establish the recovery survey area. In 1998, sockeye expanded the upper limit of their distribution in the Birkenhead and upper Pitt rivers. The Birkenhead recovery survey was adjusted to encompass the new area; the Pitt was not. In all other projects, the 1998 recovery surveys encompassed the entire known spawning area.

Temporal and Spatial Allocation of Survey Effort: There were no significant departures from the objective of standard daily capture effort or quotas based on live counts. Similarly, there were regular recovery surveys through-out the die-off, with crew sizes increased during periods of high carcass abundance to allow the maintenance of the recovery cycle.

Carcass Resurveys: The percentage of the recovered carcasses misidentified as untagged is estimated by resurveying a sub-sample of the die-

Table 5. Primary and secondary disk tag loss, by sex, in the 1998 Fraser River sockeye salmon mark-recapture studies.

	Males						Females					
		Missing tags			Tag loss rate			Missing tags			Tag loss rate	
Study	Total tagged [a]	1°	2°	Both	1° tag	2° tag	Total tagged [a]	1°	2°	Both	1° tag	2° tag
Adams	845	11	1	0.01	1.3%	0.1%	691	0	5	0.00	0.0%	0.7%
Birkenhead	403	3	2	0.01	0.7%	0.5%	421	1	2	0.00	0.2%	0.5%
Chilko	733	0	16	0.00	0.0%	2.2%	850	1	14	0.02	0.1%	1.6%
Eagle	10	1	0	0.00	10.0%	0.0%	10	0	0	0.00	0.0%	0.0%
Horsefly	591	4	4	0.03	0.7%	0.7%	495	1	2	0.00	0.2%	0.4%
Middle	65	0	3	0.00	0.0%	4.6%	74	0	5	0.00	0.0%	6.8%
Mitchell	219	0	1	0.00	0.0%	0.5%	208	0	1	0.00	0.0%	0.5%
Pitt	36	0	1	0.00	0.0%	2.8%	46	0	1	0.00	0.0%	2.2%
Seymour	51	0	1	0.00	0.0%	2.0%	68	0	3	0.00	0.0%	4.4%
Shuswap	351	2	0	0.00	0.6%	0.0%	287	1	2	0.01	0.3%	0.7%
Tachie	40	0	0	0.00	0.0%	0.0%	65	0	0	0.00	0.0%	0.0%
Weaver	98	0	0	0.00	0.0%	0.0%	83	0	0	0.00	0.0%	0.0%
Total	3,441	21	29	0.05	0.6%	0.8%	3,298	4	35	0.03	0.1%	1.1%

[a] Total tagged includes a trivial number of recoveries estimated to have lost both tags.

off. The resurveys were frequent and extensive, recovering an average 45% of the previously surveyed carcasses (considerably higher than in recent years) (Table 4). In only two studies, Tachie (10%) and Seymour (15%), were less than 30% of the carcasses resurveyed (thus, the estimate is relatively imprecise for these studies). The number of tagged carcasses misidentified as untagged was low in all studies, with an average of 1.2% and a high of 3.6% in Birkenhead (Table 4). This was a substantial improvement over recent years, *e.g.*, in 1994 the missed tag rate averaged 7.6% with a high of 20% (Schubert 1998).

Tag Loss: The loss of primary and secondary tags averages 0.6% and 0.8% in males and 0.1% and 1.1% in females, respectively (Table 5). Because primary and secondary tags had very low loss rates, the probability that a fish lost both tags (the product of the two loss rates) is also very low. The new procedures introduced in 1998 are a substantial improvement over previous years when high secondary tag loss (spaghetti tags) or observer recognition error (opercular punches) hindered the interpretation of results.

Tagging and Recovery Rates: The studies are designed to tag 1% and recover either 10% (Chilko, Horsefly) or 20% of the population. The average tagging rates approximated 1%, at 1.3% (of the estimated population) for both sexes (Table 4). All studies had tag rates of 0.8% or greater, except the Eagle where only 0.5% of the population was tagged. Similarly, the average recovery rates approximated 20%, at 21% and 19% for males and females, respectively (Table 4). Five studies recovered less than 15% of the population: Pitt (9%), Horsefly (12%; expected due to subsampling of recovery areas), Mitchell (13%), Seymour (13%), Tachie (14%) and Eagle (15%) (Table 4). Regardless, the precision goal of ±25% of the population estimate was achieved in all studies except the Eagle (52% for males and females) and Pitt (30% for males and 27% for females) (Table 6). This reflects the fact that, because precision is determined by the number of tags recovered, it results from an interaction of both tagging and recovery rates. Low tag rates in the Eagle reflect the difficulty in identifying appropriate tagging sites and capture methods in the first year of this mark-recapture study. Low recovery rates in the Eagle reflect the small crew size and poor visibility in the turbid, glacial run-off. The extremely low recovery rates in the Pitt study result from the extensive spawning area and the difficult viewing conditions that result from glacial run-off and spawning in the river's mainstem.

Summary: All of the 1998 mark-recapture studies were well designed and executed in most

Table 6. Tag application and recovery samples, escapement estimates and 95% confidence limits for the 1998 Fraser River sockeye stocks estimated using mark-recapture studies.

	Adult males [a]					Adult females [a]				
	Tag application	Carcass recovery		Escapement [b]		Tag application	Carcass recovery		Escapement [b]	
Study		Tagged	Total	Estimate	+/-		Tagged	Total	Estimate	+/-
Adams	5,360	845	80,655	507,322	6%	4,724	691	79,492	539,802	7%
Birkenhead	1,207	403	38,213	114,299	8%	1,634	421	46,767	181,370	8%
Chilko	3,011	733	89,568	367,336	6%	3,860	850	112,748	511,674	6%
Eagle	73	10	1,946	12,321	52%	74	10	2,513	16,157	52%
Horsefly	4,911	591	45,296	373,601	7%	4,295	495	42,954	369,521	8%
Middle	283	65	4,501	19,400	21%	295	74	4,948	19,506	19%
Mitchell	1,663	219	18,634	136,240	12%	1,755	208	20,058	163,680	13%
Pitt	365	36	2,807	27,753	30%	522	46	4,366	49,135	27%
Seymour	463	51	2,123	18,604	25%	433	68	2,392	14,774	21%
Shuswap	1,619	351	32,446	142,094	9%	1,410	287	32,516	149,537	10%
Tachie	309	40	6,224	47,066	28%	420	65	7,187	45,897	22%
Weaver [c]	180	98	3,539	13,188	13%	198	83	2,916	14,832	16%
Total	19,444	3,442	325,952	1,779,224	3%	19,620	3,298	358,857	2,075,885	2%

[a] Tagging and recovery totals are not adjusted (see *Analytic Procedures*).

[b] PPE estimate with 95% confidence intervals.

[c] Includes upper creek.

aspects. The distribution of application, recovery and resurvey effort improved slightly over recent years for most studies, while the improvement since 1994 (Schubert 1998) and 1995 (Schubert 2007), the most recent years that the studies are fully documented, is dramatic. This results from an increased emphasis on training the field crews regarding the importance of study design execution. When tagging began late, the temporal pattern of tag incidence does not indicate an impact on proportional tagging. Application and recovery was also sufficient, in most cases, to achieve the precision target; only the Eagle and Pitt studies were relatively imprecise. Two concerns persist in the distribution of carcass recovery effort. First, recovery appeared to end early in the Chilko and Pitt studies, as indicated by the temporal patterns in the recovery rate of tagged sockeye. Second, the Pitt recovery area did not encompass the entire spawning distribution.

Stress

Arrival Condition: To evaluate the potential impact of the condition of sockeye arriving on the spawning grounds on estimation accuracy, we examine the proportion that required ventilation after release, the proportion recaptured at the tag site, time out between tagging and carcass recovery, and average female spawning success (Table 7). An average 2.4% of the fish required ventilation after tagging, with unusually high rates in Middle (6.5%), Weaver (6.6%) and early Stuart (10.8%) (Fig. 2) (1994-1997 average 1.5%; range 0%-9.2%). The values for Weaver and Stuart are extreme both in 1998 and relative to previous years in the same studies (Weaver: 0.4% in 1996; Stuart: 0.4% in 1996, 5.4% in 1997), but similar to extreme values reported in 1994 for Middle and Stellako sockeye.

In studies where the number and location of tagging sites has not changed from previous years, the proportion of previously tagged fish that were recaptured at the tagging site is not unusually high relative to 1994-1997 (Table 7; Fig. 2).

The mean time between application and recovery (*i.e.*, days out) is quite constant between 1994 and 1998 for most studies except Pitt, Weaver and early Stuart (Table 7; Fig. 2). The change in the former two stocks reflects study design modifications. In the Pitt, the tagging site was moved from the spawning grounds to the migratory route and tagging started earlier. In Weaver, the shorter time out (by almost three days) is an artifact of more frequent recovery surveys in 1998, reducing the time between death and recovery.

Table 7. Indicators of the condition of sockeye salmon spawning in mark-recapture study areas from 1994 to 1998. Values are for combined sex data (see Appendix 2 for values specific to sex and tag application method).

Study	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
	Proportion requiring ventilation at release (%)					*Proportion recaptured liveone or more times (%)*				
Adams	0.1%	0.1%	-	-	0.3%	10.4%	6.8%	-	-	4.7%
Birkenhead	1.7%	0.0%	0.2%	1.2%	0.2%	9.5%	-	18.4%	19.1%	3.5%
Chilko [a]	0.4%	0.1%	0.1%	0.5%	1.0%	0.1%	0.0%	0.6%	0.4%	0.3%
Eagle	-	-	-	-	3.4%	-	-	-	-	4.1%
Horsefly [a]	2.0%	1.1%	-	0.2%	1.1%	3.6%	4.7%	-	7.1%	8.5%
Middle	9.2%	-	-	0.5%	6.5%	34.5%	-	-	1.9%	10.3%
Mitchell [a]	0.1%	-	-	1.0%	0.1%	0.7%	-	-	6.5%	2.5%
Pitt	-	-	0.7%	2.9%	0.1%	-	-	0.9%	5.1%	7.6%
Seymour	0.7%	0.1%	-	-	0.9%	5.1%	7.1%	-	-	19.9%
Shuswap [a]	0.6%	-	-	-	0.2%	0.3%	-	-	-	2.8%
Stellako	8.1%	3.8%	1.7%	-	0.4%	-	-	-	-	-
Stuart early	-	-	0.4%	5.4%	10.8%	-	-	-	-	-
Tachie	2.8%	-	-	0.5%	1.2%	11.2%	-	-	4.8%	7.8%
Weaver [a]	-	-	0.4%	-	6.6%	-	-	1.7%	-	1.5%
	Mean time between application and recovery (days)					*Mean spawning success (%)*				
Adams	13.8	13.7	-	-	12.8	99.5%	93.7%	91.5%	94.7%	97.7%
Birkenhead	17.5	15.9	19.2	21.7	21.5	99.8%	92.0%	91.9%	94.8%	95.4%
Chilko	28.6	31.6	32.1	27.3	31.6	97.1%	93.5%	94.8%	91.5%	92.2%
Eagle	-	-	-	-	11.4	87.5%	100.0%	96.3%	90.1%	97.3%
Horsefly	17.5	15.9	-	15.7	16.0	99.0%	97.3%	94.7%	93.3%	89.1%
Middle	14.4	-	-	18.6	17.6	99.5%	100.0%	86.4%	95.5%	98.6%
Mitchell	14.7	-	-	13.5	14.7	99.7%	97.4%	100.0%	92.7%	94.6%
Pitt	-	-	14.0	18.7	37.5	98.3%	90.0%	95.7%	91.2%	96.9%
Seymour	11.7	12.9	-	-	12.5	98.9%	98.3%	95.0%	84.6%	96.7%
Shuswap	15.7	-	-	-	15.8	99.1%	100.0%	89.3%	66.7%	96.3%
Stellako	21.6	18.1	26.1	-	22.2	89.1%	74.9%	93.4%	-	98.4%
Stuart early	-	-	11.4	5.8	8.7	91.6%	88.7%	96.5%	76.0%	52.0%
Tachie	17.0	-	-	16.4	15.4	97.0%	100.0%	84.7%	87.5%	98.4%
Weaver	9.1	-	8.4	-	6.0	97.9%	56.0%	48.7%	50.7%	90.4%

[a] Studies in which tagging locations have been essentially constant over the years examined; important to interpretation of recaptures.

The time out in the Stuart study in 1998 (8.7 days) is longer than in 1997 (5.8 days); however, 1997 was abnormally low due to the exhausted state of returning sockeye. Time out in 1998 is approximately three days shorter than in 1996, when the sockeye appeared in better condition. Further, the mean days between the median arrival date (the date when 50% of the return was counted through the fence) and the median carcass recovery date is five days shorter than the average between 1988 and 1997 (MacDonald *et al.* 2000). Thus, the Stuart early run stocks appear to have died earlier than normal.

Finally, mean spawning success averages 92% (96% if Stuart is excluded) and is above 90% in all but the Horsefly (89%) and early Stuart (52%) (Table 7; Fig. 2). In fact, the 1998 level exceeds the 1994-1997 average in all stocks but Chilko, Horsefly, Mitchell and Stuart. Spawning success of the Stuart stocks is extremely low, both relative to the other stocks examined and to the same stocks in previous years (Fig. 2).

Handling Stress: To examine whether capture and handling stress may have represented the 'last straw' by altering the behaviour and re-

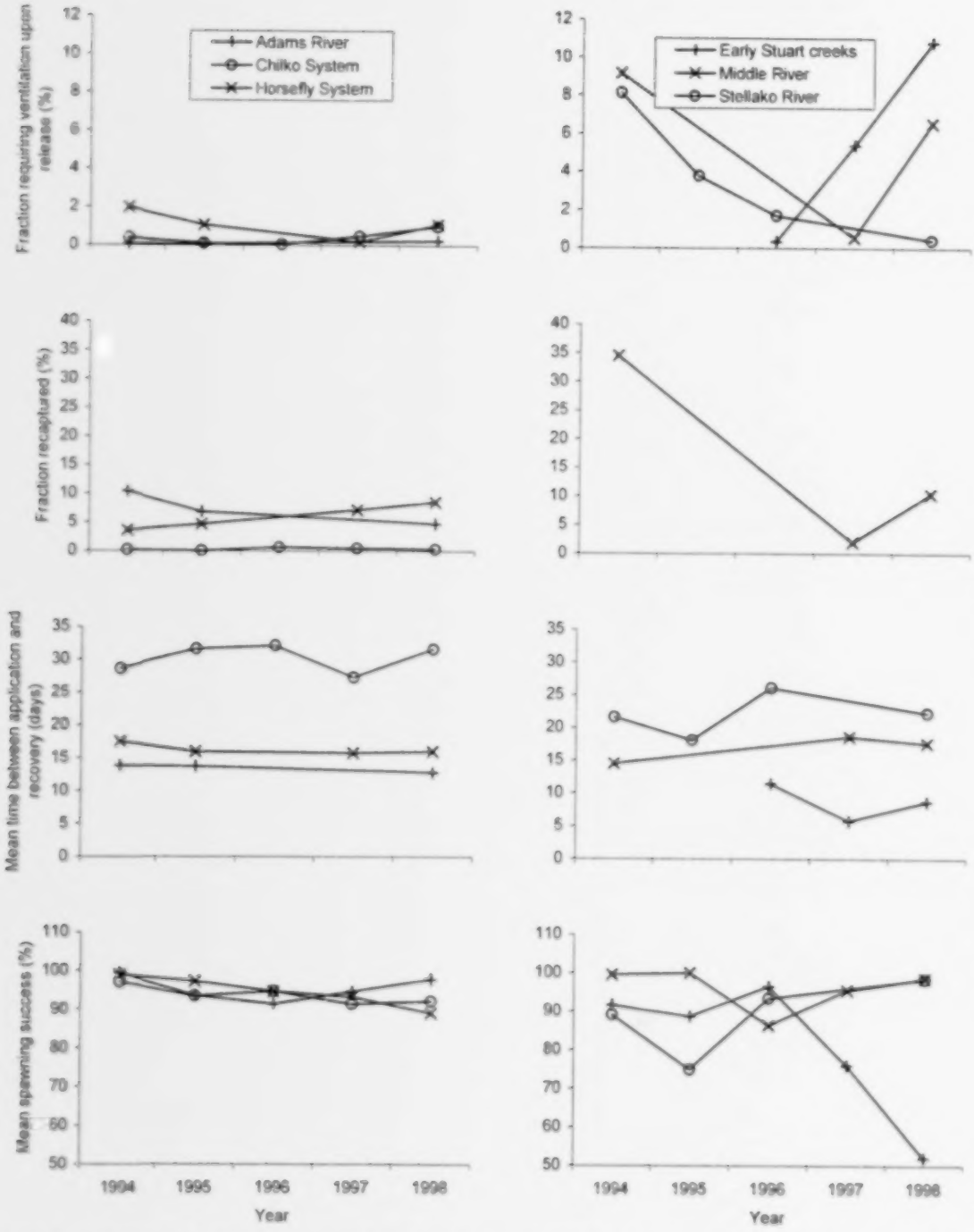


Figure 2. Condition indicators versus year for the period 1994-1998 for six projects: Adams, Chilko, Horsefly, Stuart Early Run (Forfar, Gluske and Kynoch creeks combined), Middle and Stellako.

Table 8. Recovery rates of sockeye salmon in high and low stress categories, and the fraction of the tagged and untagged sockeye salmon that spawned successfully, in the 1998 Fraser River mark-recapture studies.

		Recovery rate						Percent spawned		
		Required ventilation at release?			Recaptured?			Tagged?		
Sex	Study	No	Yes	Δ	No	Yes	Δ	No	Yes	Δ
Females	Adams	14.8%	30.0%	15.2% [a]	14.8%	15.8%	1.0% [a]	95.4%	94.0%	1.4% [a]
	Birkenhead	25.5%	25.0%	-0.5%	25.5%	28.6%	3.1% [a]	95.3%	91.9%	3.4% [a, b]
	Chilko	22.5%	11.1%	-11.4% [a, b]	22.4%	0.0%	-22.4%	85.7%	94.9%	-9.2% [a, b]
	Eagle	12.3%	100.0%	87.7%	13.5%	-	-	96.9%	90.0%	6.9%
	Horsefly	10.2%	8.7%	-1.5% [a]	10.2%	10.9%	0.7% [a, b]	83.6%	80.1%	3.5% [a, b]
	Middle	33.1%	2.4%	-30.7% [a]	29.0%	37.9%	8.9% [a]	98.4%	97.1%	1.3%
	Mitchell	11.5%	0.0%	-11.5%	11.7%	7.7%	-4.0% [a]	92.1%	94.6%	-2.5% [a]
	Pitt	8.2%	-	-	8.4%	6.7%	-1.7% [a]	96.3%	87.5%	8.8% [a]
	Seymour	16.7%	25.0%	8.3%	16.6%	17.3%	0.7% [a]	96.3%	94.4%	1.9% [a]
	Shuswap	20.0%	0.0%	-20.0% [b]	19.8%	27.5%	7.7% [a]	92.6%	96.7%	-4.1% [a, b]
	Stellako	35.5%	0.0%	-35.5%	0.0%	-	-	98.4%	95.4%	3.0% [a]
	Stuart early	64.3%	-	-	-	-	-	50.0%	22.2%	27.8%
	Tachie	15.4%	40.0%	24.6%	16.4%	11.4%	-5.0% [a]	98.3%	98.2%	0.1% [a]
	Weaver	43.4%	50.0%	6.6% [a]	43.7%	100.0%	56.3%	89.4%	79.1%	10.3%
Males	Adams	15.9%	23.1%	7.2% [a]	16.1%	12.0%	-4.1% [a]	-	-	-
	Birkenhead	30.7%	33.3%	2.6%	31.5%	21.6%	-9.9% [a]	-	-	-
	Chilko	23.3%	26.1%	2.8% [a]	23.3%	8.3%	-15.0% [a]	-	-	-
	Eagle	13.0%	25.0%	12.0%	13.4%	16.7%	3.3%	-	-	-
	Horsefly	10.9%	12.5%	1.6% [a]	11.0%	10.2%	-0.8% [a]	-	-	-
	Middle	27.6%	33.3%	5.7%	25.6%	42.2%	16.6% [a]	-	-	-
	Mitchell	12.6%	25.0%	12.4% [b]	12.7%	10.2%	-2.5% [a]	-	-	-
	Pitt	9.8%	0.0%	-9.8%	9.9%	8.0%	-1.9% [a]	-	-	-
	Seymour	11.7%	0.0%	-11.7%	11.0%	13.6%	2.6% [a]	-	-	-
	Shuswap	21.8%	33.3%	11.5%	21.8%	20.0%	-1.8% [a]	-	-	-
	Stellako	52.4%	0.0%	-52.4%	0.0%	-	-	-	-	-
	Stuart early	42.1%	50.0%	7.9%	-	-	-	-	-	-
	Tachie	12.7%	0.0%	-12.7%	11.8%	18.2%	6.4% [a]	-	-	-
	Weaver	55.3%	66.7%	11.4% [a]	56.1%	100.0%	43.9%	-	-	-

[a] N > 10 in the high stress category.

[b] Difference is statistically significant ($p<0.05$, chi-square test).

covery probability of tagged sockeye, we evaluate recovery rates of fish that required ventilation at release or were recaptured at the tagging site, spawning success between tagged and untagged females, and the influence of tag status on the recovery distribution of carcasses.

Ventilation: Little insight is provided by comparisons of recovery rates of ventilated sockeye across years because, in most projects and years, less than ten releases required ventilation. Only in the Chilko, Horsefly and Middle studies are sample sizes greater than ten in both 1998 and any previous year (Table 8; Appendix 3). In the Chilko, the difference in recovery rate for females is much greater in 1998 than 1997. In the Horsefly, the difference in recovery rates is small for both sexes. Finally, the difference in recovery rates of females in the Middle study is greater (and opposite in sign) in 1998 than 1994 and 1997. Even in this case, though, the difference in recovery rates between ventilated and non-ventilated females in 1998 is not significant.

Recapture: The number of sockeye recaptured is generally much larger than the number

ventilated; therefore the recovery rate of recaptured fish is limited to a sample of ten or more releases. The difference in recovery rates of recaptured and non-recaptured sockeye is unusual in the Birkenhead (males), Chilko (males) and Middle (both sexes) studies (Appendix 3). In all of these cases, however, the test for an effect of the number of times recaptured on recovery rate is not significant.

Spawning Success: In most projects, the difference in the fraction of tagged and untagged recovered females that had completely spawned is not unusual. The Chilko and Pitt study results are an exception (among those in which ten or more tagged females were recovered). The Chilko, however, is in the direction opposite to that generally expected if tagging is stressful and thus does not support the interpretation that females were unusually stressed. In the Pitt, fewer tagged than untagged females were completely spawned (Appendix 3). This result is weak evidence that Pitt females were somewhat stressed by tagging.

Tag Distribution: Finally, we compare spatial patterns of tag incidence across 1994-1998 to examine the influence of tag status on the recovery distribution (presumably indicative of the spawning distribution). In 1998, if tagging was the last straw for a larger fraction of tagged fish than normal, the tag distribution should be more skewed toward the lower river than in previous years. Such a change occurred only in the Horsefly and Pitt projects (Appendix 4).

Summary: Overall, the 1998 condition indicators are similar to recent years. The most atypical is the Stuart early run, where the fraction requiring ventilation, the days out and the spawning success are all low compared to typical years. As well, the fraction requiring ventilation is twice as high as in 1997 and the spawning success is approximately two thirds of the low 1997 level. These results suggest that sockeye returning to the Stuart were in poor condition, while those returning to other rivers arrived in normal condition. The comparisons of recovery rates, spawning success and spatial patterns of tag incidence between sockeye that had not experienced additional stress generally does not support the view that tagging was the last straw for a larger fraction of returning sockeye than normal. The strongest evidence of a stress effect is for the Horsefly and Pitt studies. We note, however, that while Horsefly sockeye were subject to adverse environmental conditions over their protracted migration through the Fraser River, Pitt sockeye were not.

Bias Assessment

The sampling biases detected (significant test result) in the 1998 data are described in Table 9. Appendix 1 provides the bias test results for all studies from 1994 to 1998; sex bias is not reported because the mark-recapture estimates are calculated separately for the two sexes.

Size Bias: The test for size bias at recovery is only significant for females in the Adams; larger females had a higher recovery rate. Untagged carcasses were not measured during recovery, and thus no test for size bias at application can be performed; however, sockeye were captured for tagging using beach seine nets, a capture gear that is unlikely to be selective by size. Furthermore, unless the source of selectivity in the application sample is correlated with a source of selectivity in the recovery sample, bias will not be introduced in the estimate (Junge 1963). In the studies examined here, there is no indication that fish size influences recovery distribution, either temporally or spatially; therefore, the population estimates are unlikely to be biased due to size-bias in sampling.

Temporal and Spatial Bias: Sampling profiles for the 1998 studies are presented in Appendix 5. The evaluations of the influence of temporal and spatial sampling biases on the population estimates are based on the following logic. When the probability of tagging (P_{cap}) and recovery (P_{rec}) are correlated, the Petersen mark-recapture estimate will be biased. We consider three mechanisms that can lead to such correlations in sockeye. First, the time of tagging and recovery are usually correlated, since early arrivals tend to die earlier. Second, spawning location can influence both tagging probability and recovery rates. Finally, the time of application and the area of recovery are often correlated, with earlier fish spawning further upstream. We refer to these three mechanisms as *TxT*, *SxS* and *TxS*, respectively. A similar shape in the relevant patterns of tag incidence and recovery rate (*e.g.*, temporal patterns in the Seymour study; Appendix 5) can establish a positive correlation between the probabilities of tag-

Table 9. Results of statistical tests for sampling bias in the mark-recapture studies of Fraser River sockeye salmon in 1998. For significant tests, the bias is described (non-significant tests are indicated by *No bias*); when bias is detected in only one stratification, the stratification type is indicated as equal periods (EP), effort (EE) or recoveries (ER). [a]

		Male		Female	
Study	Test type	Application	Recovery	Application	Recovery
Adams	Temporal	↑ t.i. early, ↓ t.i. late	No bias	↑ t.i. early, ↓ t.i. middle	No bias
	Spatial	↓ t.i. Shuswap L., Little R.	↓ r.r. from 'OO' to mouth	↓ t.i. in Shus. L, Little R.	↓ r.r. at mouth
	Fish sex	↑ than expected t.i.	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Birken-head	Temporal	↑ t.i. early	No bias	↑ t.i. early	No bias
	Spatial	No bias	Primary ↓ r.r., 2° ↑ r.r.	↓ t.i. in upper reaches	No bias
	Fish sex	No bias	↑ than expected r.r.	No bias	↓ than expected r.r.
	Fish size	Not applicable	No bias	Not applicable	No bias
Chilko	Temporal	No bias	↓ r.r. early	Declining t.i.	↓ r.r. early
	Spatial	No bias	Not applicable	No bias	Not applicable
	Fish sex	No bias	↑ than expected r.r.	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Eagle	Temporal	No bias	No bias	↓ t.i. early (EP)	No bias
	Spatial	No bias	No bias	No bias	No bias
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Horsefly	Temporal	No bias	Complex pattern in r.r.	↓ t.i. late	↓ r.r. 2nd period (EE)
	Spatial	↑ t.i. in lower reaches	Not applicable	↑ t.i. in lower reaches	Not applicable
	Fish sex	↓ than expected t.i.	No bias	↑ than expected t.i.	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Middle	Temporal	Complex pattern (EP)	No bias	↑ t.i. early	No bias
	Spatial	↑ t.i. in lower reaches	No bias	↑ t.i. in lower river	No bias
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Mitchell	Temporal	Complex pattern in t.i.	No bias	↓ t.i. late	↓ r.r. 2nd period (EP)
	Spatial	↓ t.i. in lower reaches	Not applicable	↓ t.i. in lower reaches	Not applicable
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Pitt	Temporal	No bias	No bias	↓ t.i. late (ER)	↓ r.r. late
	Spatial	No bias	Not applicable	Complex t.i. pattern	Not applicable
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	↑ r.r. in larger females
Sey-mour	Temporal	↓ t.i. late (EP)	↓ r.r. late	No bias	No bias
	Spatial	No bias	Not applicable	No bias	Not applicable
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Shuswap	Temporal	No bias	↓ r.r. early and late (ER)	↓ t.i. late	No bias
	Spatial	No bias	Not applicable	↓ t.i. in upper reaches	Not applicable
	Fish sex	↑ than expected t.i.	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Tachie	Temporal	No bias	No bias	No bias	No bias
	Spatial	No bias	No bias	No bias	No bias
	Fish sex	No bias	No bias	No bias	No bias
	Fish size	Not applicable	No bias	Not applicable	No bias
Weaver	Temporal	↓ t.i. in first period	↓ r.r. in later period	↓ t.i. in first period	↓ r.r. late
	Spatial	No bias	Not applicable	No bias	Not applicable
	Fish sex	No bias	↑ than expected r.r.	No bias	↓ than expected r.r.
	Fish size	Not applicable	No bias	Not applicable	No bias

[a] t.i. indicates tag incidence; r.r. indicates recovery rate.

Table 10. Effect of application and recovery sampling biases on mark-recapture estimates of 1998 Fraser River sockeye salmon escapements, by sex and mechanism (see text). Effects are indicated on a qualitative scale, with <<, <, -, >, >> indicating large negative, small negative, no effect, small positive and large positive biases, respectively. *Max.* is the is the largest discrepancy between the Darroch and Petersen estimates, and *Prop'n>* is the proportion of acceptable Darroch estimates that are larger than the Petersen estimate.

	Males					Females				
	Mechanism			Darroch discrepancy		Mechanism			Darroch discrepancy	
Study	TxT	SxS	TxS	Max. [a]	Prop'n >	TxT	SxS	TxS	Max. [a]	Prop'n >
Adams	-	<	-	2.5%	3/3	>>	>>	-	-5.0%	0/2
Birkenhead	>	>	-	2.9%	1/3	>	>	-	-3.6%	2/3
Chilko	-	>	-	4.0%	1/2	>>	>	-	-6.9%	1/2
Eagle	-	>	-	9.0%	2/2	-	-	-	23.5%	3/3
Horsefly	<	-	-	4.3%	1/2	-	-	-	7.3%	2/2
Middle	<	>	-	56.5%	3/3	-	>	-	10.0%	1/3
Mitchell	>	-	-	14.8%	2/2	-	-	-	-14.9%	1/2
Pitt	-	-	-	-3.9%	1/2	<<	-	-	n/a	n/a
Seymour	<<	>	-	-38.1%	1/2	<	-	-	-17.9%	2/3
Shuswap	-	-	-	1.3%	2/2	-	-	-	-0.4%	1/2
Tachie	-	-	-	30.7%	2/2	-	-	-	10.7%	2/2
Weaver	>	-	-	0.4%	1/1	<	-	-	-5.4%	0/1

[a] Discrepancies are positive when the Darroch is larger than the Petersen.

ing and recovery (and thus a negative bias). Opposite shapes (*e.g.*, temporal patterns in the Birkenhead study; Appendix 5) can create a negative correlation (and a positive bias). Flat profiles, for either sample, will not cause a correlation (no bias). Finally, differently shaped profiles (*e.g.*, temporal patterns in the Eagle study; Appendix 5) will lead to, at most, a weak correlation.

Conclusions from these evaluations (Table 10) are qualitative for two reasons. First, the shapes of the sampling profiles are usually complicated (*e.g.*, in the Birkenhead, tag incidence generally decreases through time, but increases somewhat near the end; Appendix 5). Second, the trends indicated by the data are only estimates of the true patterns in tag incidence or recovery rate. Based on the evaluation of each mechanism, we estimate whether the sampling biases would likely have caused a large negative bias, a small negative bias, no bias, a weak positive bias or a large positive bias. We consider the influence of a particular mechanism on the population estimate to be large when the relevant trend in tag incidence strongly parallels (negative bias) or opposes (positive bias) that in recovery rate and if both trends are significant. Otherwise, we consider the effect to be small. We further note that we have no way of quantifying large and small biases.

Estimation Bias: The results of the qualitative evaluation of the effects of sampling biases on the population estimates are presented in Table 10. A large biases may be present in the Adams female (+), Chilko female (+), Pitt female (-) and Seymour male (-) estimates. Small biases may be present in the Adams male (-), Birkenhead male (+) and female (+), Chilko male (+), Eagle male (+), Horsefly male (-), Middle female (+), Mitchell male (+), Seymour female (-) and Weaver male (+) and female (-) estimates. The *TxT* and *SxS* mechanisms appear to result in counteracting biases in the Seymour and Middle study; we assume that the resulting bias is likely to be small. We note that the identified biases are bi-directional, and that the positive biases (7) may offset the negative biases (5) in the total estimate.

Table 10 also presents information on the size and direction of MLE-PPE discrepancies for valid MLE estimates (those that pass Plante's G^2). Maximum discrepancies exceed 5% in the Eagle, Seymour, Mitchell, Middle and Tachie (both sexes) and in the Weaver, Adams, Chilko and Horse-

Table 11. Dates of fence installation, sockeye arrival, fence removal, and the completion of migration, and an evaluation of operational effectiveness for the 1998 Fraser River sockeye salmon enumeration fence studies.

		Date of					Downstream		
Stock Group	Stock	First arrival of sockeye	Fence installation	Completion of migration	Fence removal	Fish tight	Holding	Mortality	Peak daily count
Lower Fraser	Cultus Lake	14-Sep	14-Sep	21-Nov	23-Nov	Yes	No	No	279
Seton-Anderson	Gates Creek	08-Aug	06-Aug	07-Sep	17-Sep	Yes	No	No	500
South Thompson	Salmon River	05-Oct	30-Jun	05-Nov	Dec	Yes	No	No	17
	Scotch Creek	15-Aug	31-Jul	14-Sep	16-Sep	Yes	No	Yes	3,782
Quesnel	McKinley Creek	24-Aug	15-Aug	26-Sep	Nov	Yes	No	No	8,355
Stuart	Forfar Creek	24-Jul	17-Jul	18-Aug	19-Aug	Yes	No	No	105
	Gluske Creek	23-Jul	16-Jul	17-Aug	19-Aug	No	No	No	184
	Kynoch Creek	21-Jul	18-Jul	18-Aug	19-Aug	Yes	No	No	399
	Kuzkwa River	06-Sep	04-Sep	01-Oct	19-Oct	Yes	No	No	1,297
Nechako	Stellako River	18-Aug	17-Aug	17-Oct	19-Oct	Yes	No	No	21,166

fly (females; Table 10). We present these comparisons as maximum possible biases that, based on work in the Stellako River (Houtman and Schubert 2007), are likely to exceed the level by a considerable margin.

Summary: We cannot provide quantitative estimates of estimation biases; however, simulations examining the influence of major sampling biases on the Petersen estimates (Schubert and Fanos, 1997; Schubert and Vivian, 1997) indicate that deviations as large 10% are rare. The bi-directional biases (positive and negative) noted here represent a departure from the traditional bias structure in sockeye mark-recapture where overestimates are common (*e.g.*, Cousens *et al.* 1982). This reflects recent improvements to field procedures that have permitted a more representative distribution of tags through the populations. We suggest that the traditional bias pattern results from two common sampling biases. First, in studies where the majority of tags are applied at a single site near the bottom of the spawning distribution, tag incidence generally decreases moving upstream. This reflects the lower vulnerability to tagging of rapidly moving early migrants destined for spawning sites in the upper river (Schubert and Scarborough 1996), and the higher vulnerability of slow moving (or milling) late migrants that spawn near the tagging site in the lower river. Second, the probability that a carcass will be flushed out of the study area is lower for fish that spawn further upstream. Thus, individuals tagged at a higher rate in the lower river are less likely to be recovered than those tagged at a lower rate in the upper river, introducing a positive bias in the population estimate. Because the 1998 biases are bi-directional and off-setting, the overall bias in the mark-recapture studies is probably low.

ENUMERATION FENCE

The 17 stocks assessed by essentially complete censuses at either spawning channels (6 stocks) or fences (11 stocks) are identified in Appendix 11. These stocks account for 9% (2% and 7%, respectively) of the 1998 Fraser River sockeye escapement estimate, 181,900 males, 201,600 females and 1,700 jacks. By far the largest escapements were counted at fences in the Stellako River (185,700), and McKinley (75,800), and Scotch (36,000) creeks. The attributes of these estimates are described below.

Implementation of Study Design

In this section, we address the questions raised under *Bias Assessment* (spawning channels are not addressed because detailed operational data are unavailable): Was the fence installed after the arrival of sockeye? Were operations interrupted during the migration? Was the fence removed before the migration was complete? Did it cause fish to hold or die downstream? Did large daily abundances confound the counts?

Installation Timing: The fences were installed at least three days (and usually over a week)

before the arrival of the first sockeye (Table 11), except in Cultus, Gates, Kuzkwa and Stellako, where fence installation preceded sockeye arrival by 0, 2, 2 and 1 day, respectively. Cultus returned unusually early and is likely estimated with a small negative bias, while Gates, Kuzkwa and Stellako are likely unbiased because no sockeye were observed in the river following fence installation. In all cases, the fences operated until at least two days of zero counts were recorded and downstream surveys reported no new sockeye. The fences were maintained without incident and likely intercepted all immigrants, except in Gluske where a breech in the live box for two days early in the study permitted fish to enter the box and jump its wall. The counts were corrected from intensive creek surveys that, because the creek is small and abundance was low, approximate a complete census.

Obstruction of Migration: There was one significant observation of fish holding or dying below the enumeration fences: Scotch Creek. Because flows were low near the creek mouth, project staff sandbagged the creek to create a deeper channel; some mortality occurred when vandals removed the sand bags causing the channel to de-water.

Peak Migration: Daily migrations generally were less than 1,500 sockeye, except in Scotch (3,782) and McKinley (8,355) creeks and Stellako River (21,166) (Table 11). These large daily migrations are unlikely to introduce error in the counts because the migrations were pulsed over the entire 24-hour period, the number of sockeye in each pulse was strictly controlled, and multiple crews were used to avoid observer fatigue.

Summary: The enumeration fence studies were well executed in 1998. With only minor exceptions, the fences were fish-tight and operated over the entire immigration periods. The fences did not obstruct upstream passage and, while daily abundances were sometimes large, they were anticipated and operational procedures were in place to accommodate them.

Bias Assessment

Total counts of live or dead fish are considered to be accurate measures of spawning escapement. Errors can occur, however, for a number of reasons: a) sex and species misidentification when live fish are counted while swimming past a fixed point; b) inaccurate counts at night due to poor lighting, surface glare or viewer fatigue, or at any time when there is a rapid migration of large numbers of fish; and c) inaccurate channel counts due to the loss of carcasses to predators or washouts. For these reasons, Andrew and Webb (1987) recommend that a coefficient of variation of 5% be assigned to all complete counts. This roughly translates into 95% confidence limits of ±10%. We believe that this over-states the probable error in 1998 because the study designs addressed the first three issues: sex was not recorded from live fish; spawning colouration makes sockeye highly recognizable; night observations were avoided when possible and supported by adequate lighting when necessary; and high daily abundances were anticipated and accommodated. While a 10% error may be reasonable during the peak migration when 20,000 or more fish may be counted, it over-states the error in the balance of the run and does not apply to the smaller populations. It also ignores the likelihood of asymmetric confidence intervals, *i.e.*, underestimates would be more probable than overestimates. We conclude, therefore, that the fence and channel estimates are likely estimated with a negative bias of less than 5%.

VISUAL SURVEYS

The 144 stocks assessed using visual techniques are identified in Appendix 11. These stocks account for 4% of the 1998 Fraser River sockeye escapement estimate, 85,000 males, 98,500 females and 300 jacks.

Implementation of Study Design

In this section, we address the questions raised under *Bias Assessment*: Were visual surveys limited to small (<25,000) populations? Was the extent and frequency of the surveys adequate? Did local conditions permit the effective observation of fish?

Population Size: Of the stocks surveyed, 44% had fewer than 100 spawners, while only one (Portage Creek) had slightly more than the maximum 25,000 spawners intended for assessment by this technique (Table 12; Appendix 11). The relatively large size of the Portage population and

Table 12. The number of stocks with estimated escapements of greater than 25,000 sockeye, with peak live counts on the first or last survey, and with total survey effort of 1, 2-3, 4-6, and 7+ surveys, among the Fraser sockeye populations where the 1998 escapement is estimated using visual techniques.

				Number of stocks by survey frequency and average estimated escapement for those stocks [d]							
				1 survey		2-3 surveys		4-6 surveys		7+ surveys	
Geographic area [a]	Number of stocks surveyed [b]	25,000+ Escapement	Peak on first or last survey [c]	No. stocks	Escapement	No. stocks	Escapement	No. stocks	Escapement	No stocks	Escapement
Lower Fraser	4	0	0	0	-	1	1,600	3	2,500	0	-
Harrison-Lillooet	5	0	1	1	0	2	400	1	6,000	1	4,500
Seton-Anderson	2	1	1	0	-	0	-	1	25,200	1	1,100
South Thompson (ES)	18	0	1	3	0	4	60	7	6,100	4	1,000
South Thompson (L)	27	0	6	0	-	7	100	15	800	4	6,800
North Thompson	3	0	0	0	-	1	9	2	8,000	0	-
Chilcotin	2	0	0	2	200	0	-	0	-	0	-
Quesnel	44	0	0	16	34	11	46	17	2,000	0	-
Stuart, Early Run	41	0	1	6	1,600	5	400	1	0	29	600
Stuart, Summer Run	4	0	1	0	-	2	50	1	1,300	1	2,200
Nechako	1	0	0	0	-	1	800	0	-	0	-
Upper Fraser	2	0	0	1	0	1	4,800	0	-	0	-
Total/mean	152	1	11	29	360	35	340	48	3,020	40	1,500

[a] ES - Early Summer Run; L - Late Run.

[b] Excludes stocks or components of stocks where other techniques (fence or mark-recapture) were used to estimate the escapement, or where other agencies conducted visual surveys but did not provide the daily counts.

[c] Excludes stocks that were surveyed only once or twice, and below-fence surveys that intentionally started late to permit upriver spawners to clear the area.

[d] Average escapements greater than 100 are rounded to the nearest 100.

the small size of the creek resulted in high spawner densities that made counting difficult.

Survey Extent: The entire spawning area was surveyed for each stock, except when extremely low water levels prevented the access of fish into the stream. When that occurred (largely in tributaries to Quesnel and Shuswap lakes), the survey was limited to observations off the creek mouth. Because such blockages induce straying to other spawning areas, efforts were made to inspect non-traditional spawning areas when transiting between streams.

Survey Frequency: Each stream was surveyed 1-12 times (Appendices 9-10), with survey frequency determined by population size, or the size of the dominant population when a number of stocks were surveyed as a group. Of the streams surveyed 1-3 times, 78% had estimated populations of <100 spawners, while 86% of those surveyed 4+ times had >100 spawners (40% had 1,000+ spawners). Exceptions are largely limited to remote areas that preclude frequent access: Driftwood River (1 survey; 9,227 spawners); and Taseko Lake (1 survey; 400 spawners). When survey effort is limited, the level of carcass recovery is often insufficient to estimate sex composition; this occurred in 26 cases in 1998 (Appendix 10).

Sighting Conditions: Conditions were generally good, reflecting low water levels through most of the season. The few cases of poor visibility resulted from glacial run-off (upper Adams) or spawning in deep water (Harrison, South Thompson).

Bias Assessment

Bias in visual surveys can take several forms: the inappropriate use of visual surveys for large stocks; survey frequency that is inadequate to identify the peak of abundance; the use of a fixed

expansion factor under variable survey conditions; the failure to survey the complete distribution of a stock; or the failure to survey a stock at all.

Population Size: The use of visual surveys on large stocks is limited to one case (Portage Creek) in 1998. It is generally accepted that such surveys result in escapement estimates with a substantial negative bias. For example, in a comparison of visual and mark-recapture estimates in Middle, Mitchell and Tachie rivers in 1994, Schubert (1998) reported that the latter averaged 4.9 times larger than the former. It is unlikely that the magnitude of the bias is this high in the Portage estimate because the creek is small and the spawning area much less extensive. Regardless, the bias is likely substantial because of high densities of spawners are difficult to count and the stream surveys began after spawners had arrived (the peak observation was on the first survey) (Appendix 9).

Fixed Expansion Factor: The application of a fixed expansion factor to stream survey data clearly results in estimation error. The reliability of this technique is dependent on stream characteristics (morphology, clarity, *etc.*), climatic conditions, survey intensity and observer efficiency being similar in the index stream and the stream or streams where the expansion factor is calculated. Error occurs when there is variability between streams within a year if, for example, discharge patterns differ between geographic parts of the watershed, or even within streams among years. Cousens *et al.* (1982) note that the method could be as accurate as ±30% when observations were made by experienced observers in small, clear, stable streams. Because a large number of streams are surveyed using this technique, however, central tendency may balance over and under-estimates, resulting in less biased estimates for the aggregate. Regardless, these stocks comprise a very small proportion of the total escapement in 1998. Even gross errors, therefore, would introduce a relatively small bias in the overall escapement estimate.

Inseason Calibration: The early Stuart assessment is a refinement of this technique because the expansion factor is recalibrated each year. Data from three streams are used in 1998 to calibrate the year-specific expansion factor; therefore, the factors should accurately index the streams that are surveyed at the same level of frequency as the calibration streams. This is the case for most streams in the stock group (Appendix 10), with the exception of the Driftwood River system (1-3 surveys). The Driftwood River was surveyed by helicopter, with the date of the flight selected to coincide with the peak of abundance in streams in the northeast arm of Takla Lake. The probability of an underestimate is greater in the Driftwood because the single flight may not have coincided with the actual peak of abundance. The estimate for the Driftwood system, therefore, may have a negative bias of perhaps as high as 20% (it cannot be quantified from the available data). Given the spawner distributions observed in 1998, this would introduce a negative bias in the early Stuart estimate of about 8%.

Unsurveyed Areas: Another potential bias stems from spawning areas that are not surveyed, a possibility that was identified in 1994 (Anon. 1995a). In 1998, low water prevented spawner entry into several natal areas; these fish may have spawned in nontraditional areas. All of the known spawning areas were surveyed frequently in 1998, and the surveys include (in transit) observations of nontraditional areas. We do not eliminate the possibility of spawning in nontraditional areas that was not assessed by our surveys; however, if present, its magnitude is likely small and probably no different than in past years.

Summary: It is not possible to quantify the bias in visual estimates from the available data. It is likely, however, that the escapement of these stocks is under-estimated in 1998. In the early Stuart group, the bulk of the stocks are likely estimated accurately; however, the use of a single survey in the Driftwood River may introduce a negative bias of up to 8%. For the balance of the stocks that were not calibrated inseason, there are likely random errors of up to ±30%; however, over and under-estimates may compensate to produce a less biased aggregate estimate. The exceptions are the large escapement to Portage Creek, and the stocks spawning in glacial (upper Adams) or deep (Harrison, South Thompson) water where the negative bias may be substantial.

TOTAL ESCAPEMENT

The 1998 Fraser River sockeye escapement totals 4,422,075 adults and 5,604 jacks (Table

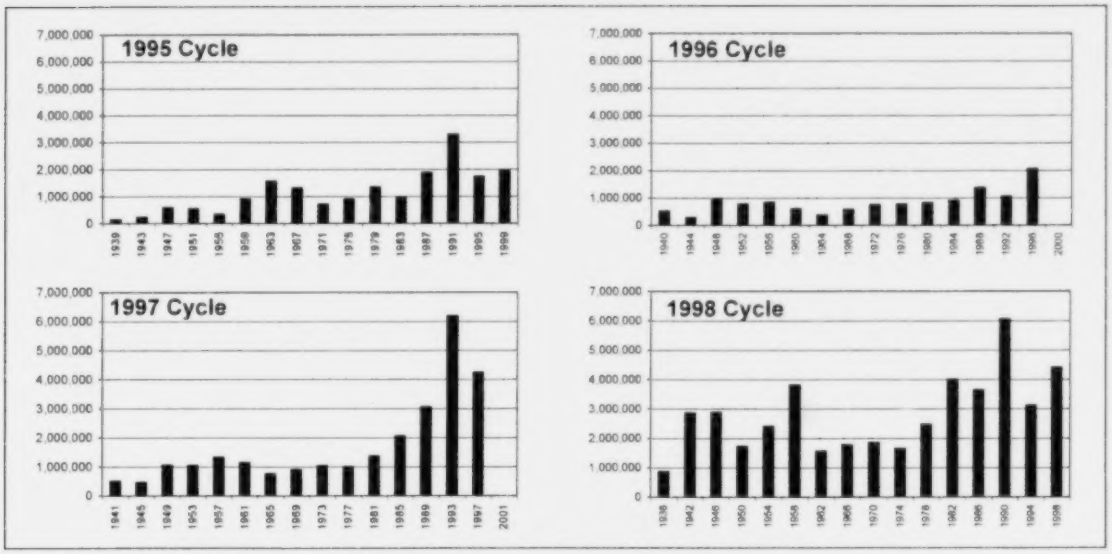


Fig. 3. Fraser River adult sockeye escapement by cycle.

13). The sockeye adult escapement increased by 41% from the 1994 brood year escapement of 3,128,543, but declined by 27% from the record 1990 escapement of 6,064,285. The 1998 escapement is the second largest reported on this cycle and the third largest regardless of cycle since 1938 (Fig. 3).

GEOGRAPHIC GROUP

Lower Fraser

The Lower Fraser group consists of five Early Summer Run and five Late Run stocks from relatively small streams that enter the Fraser River between the Pitt and Thompson rivers (Fig. 4). The largest stocks on this cycle spawn in the upper Pitt and Nahatlatch systems. Most of the Lower Fraser stocks were surveyed visually, with three to five surveys per stock (Appendix 10). Cultus Lake sockeye were enumerated at a fence in Sweltzer Creek (Appendix 7) that has operated most years since 1926. The upper Pitt escapement is estimated from a mark-recapture study, the first structured study with the primary objective to estimate the escapement of this stock. Previous studies, conducted since 1968, focused on hatchery brood stock acquisition rather than population estimation

The 1998 Lower Fraser group escapement of 87,978 adults and 211 jacks comprises 2% and 4%, respectively, of the Fraser River total (Table 13). The adult escapement is triple that of the brood year (Fig. 4), with virtually all of the increase resulting from the record escapement in the upper Pitt River. Average spawning success (94%; range 41%-97%) declined from the brood year (98%; range 94%-100%), with poor success in Chilliwack, Cultus and Nahatlatch lakes (Appendix 11).

The accuracy of the 1998 Lower Fraser estimates depends largely on the upper Pitt, which comprises 87% of the total. The restructuring of the Pitt study resulted in significant study design improvements over previous years. Study execution deficiencies, however, resulted in low recovery rates and relatively poor estimation precision, and may bias the estimate. The most serious concern is among females, where temporal biases may introduce negative estimation bias (Table 10) with an extreme probable bound equivalent to the upper confidence limit. Assuming random error in the visual estimates, the maximum probable bias for this group is a negative bias that is unlikely to exceed 5%.

Harrison-Lillooet

The Harrison-Lillooet group consists of seven Late Run stocks that spawn in Harrison River and its tributaries, and in streams tributary to Harrison Lake, Lillooet River and Lillooet Lake (Fig. 5). The largest stocks on this cycle spawn in the Birkenhead River, which was assessed by

Table 13. Estimated escapement of Fraser River sockeye salmon adults and jacks, by stock group and selected major stocks, for cycle years 1986, 1990, 1994 and 1998.

Stock group	Stock	1998 Period of peak spawning	Estimated sockeye adult escapement				Jack escapement 1998
			1986	1990	1994	1998	
Lower Fraser	Chilliwack Lake	Early Sep	1,164	2,230	7,910	1,068	4
	Cultus Lake	Early Dec	3,256	1,860	4,399	1,959	207
	Nahatlatch System	07-Sep to 12-Sep	8,996	7,044	6,042	7,993	0
	Pitt River, upper	15-Sep to-20-Sep	29,177	12,202	9,500	76,888	0
	Total [a]	-	**45,193**	**23,347**	**28,064**	**87,978**	**211**
Harrison-Lillooet	Birkenhead River	22-Sep to 27-Sep	335,630	166,773	39,234	295,669	369
	Harrison River	10-Nov to 15-Nov	7,265	4,515	9,515	4,496	0
	Weaver Channel	11-Oct to 16-Oct	44,892	10,396	44,939	29,071	46
	Weaver Creek	11-Oct to 16-Oct	65,846	5,969	20,017	28,020	22
	Total [a]	-	**456,671**	**189,505**	**114,432**	**364,064**	**443**
Seton-Anderson	Gates System	29-Aug to 02-Sep	3,572	5,374	3,360	7,248	1,477
	Portage Creek	25-Oct to 30-Oct	14,291	18,336	9,270	25,179	26
	Total [a]	-	**18,403**	**25,322**	**12,666**	**32,427**	**1,503**
South Thompson	Adams River, upper	02-Sep to 07-Sep	567	625	581	344	0
Early Summer Run	Eagle River	05-Sep to 10-Sep	7,138	4,147	45,452	28,478	0
	Scotch Creek	30-Aug to 03-Sep	26,624	83,388	73,180	35,981	12
	Seymour River	06-Sep to 08-Sep	126,166	272,041	56,192	33,379	11
	Total [a]	-	**167,631**	**387,623**	**206,899**	**108,576**	**25**
South Thompson	Adams River, lower	18-Oct to 25-Oct	1,325,089	2,068,378	680,269	870,919	265
Late Run	Eagle River	Early Oct	25,697	56,200	28,350	11,398	0
	Little River	18-Oct to 25-Oct	226,778	359,172	198,112	176,205	47
	Shuswap R., lower	12-Oct to 16-Oct	600,370	983,481	367,661	291,631	0
	Shuswap R., middle	09-Oct to 15-Oct	80,529	96,441	31,806	15,262	0
	Total [a]	-	**2,345,230**	**3,717,673**	**1,370,678**	**1,389,271**	**312**
North Thompson	Fennell Creek	25-Aug to 01-Sep	6,024	11,862	5,919	8,741	0
	Raft River	30-Aug to 09-Sep	2,095	630	1,712	7,198	31
	Total [a]	-	**8,190**	**12,592**	**7,671**	**15,948**	**31**
Chilcotin	Chilko Channel	25-Sep to 05-Oct	0	9,934	1,930	[c]	[c]
	Chilko River and Lake	25-Sep to 05-Oct	293,804	815,903	448,815	879,010	1,934
	Taseko Lake [b]	Early Sep	n/r	n/r	270	400	0
	Total	-	**293,804**	**825,837**	**451,015**	**879,495**	**1,934**
Quesnel	Horsefly System	07-Sep to 17-Sep	150,386	439,485	550,481	848,997	0
	Mitchell System	18-Sep to 25-Sep	30,827	43,755	129,235	310,329	0
	Quesnel Lake	07-Sep to 30-Sep	254	4,404	6,695	19,926	0
	Total [a]	-	**181,467**	**488,259**	**686,411**	**1,179,252**	**0**
Stuart	Takla System	30-Jul to 19-Aug	8,269	37,273	10,675	23,802	1
Early Run	Middle System	28-Jul to 15-Aug	16,433	43,039	13,266	5,841	19
	Trembleur System	29-Jul to 11-Aug	3,882	16,723	5,890	2,947	0
	Total	-	**28,584**	**97,035**	**29,831**	**32,570**	**20**
Stuart	Middle River	18-Sep to 24-Sep	9,940	76,500	29,573	38,906	11
Summer Run	Tachie River	26-Sep to 02-Oct	13,617	94,570	42,571	92,963	1,010
	Total [a]	-	**28,715**	**189,079**	**76,462**	**138,397**	**1,024**
Nechako	Nadina System	20-Sep to 25-Sep	3,549	6,033	2,008	3,705	19
	Stellako River	26-Sep to 05-Oct	77,177	93,920	137,995	185,641	56
	Total [a]	-	**80,726**	**100,153**	**140,034**	**189,346**	**75**
Upper Fraser	**Bowron System**	Early Sep	**3,124**	**7,860**	**4,380**	**4,751**	**26**
Total [a]	**Total**	**Adults**	**3,657,738**	**6,064,285**	**3,128,543**	**4,422,075**	
		Jacks	**59,706**	**20,546**	**4,083**	**5,604**	
		Total	**3,717,444**	**6,084,831**	**3,132,626**	**4,427,679**	

[a] Includes smaller, miscellaneous stocks; see Appendix 6.

[b] Taseko Lake was not surveyed in 1982, 1986 and 1990.

[c] Included in Chilko River and Lake.

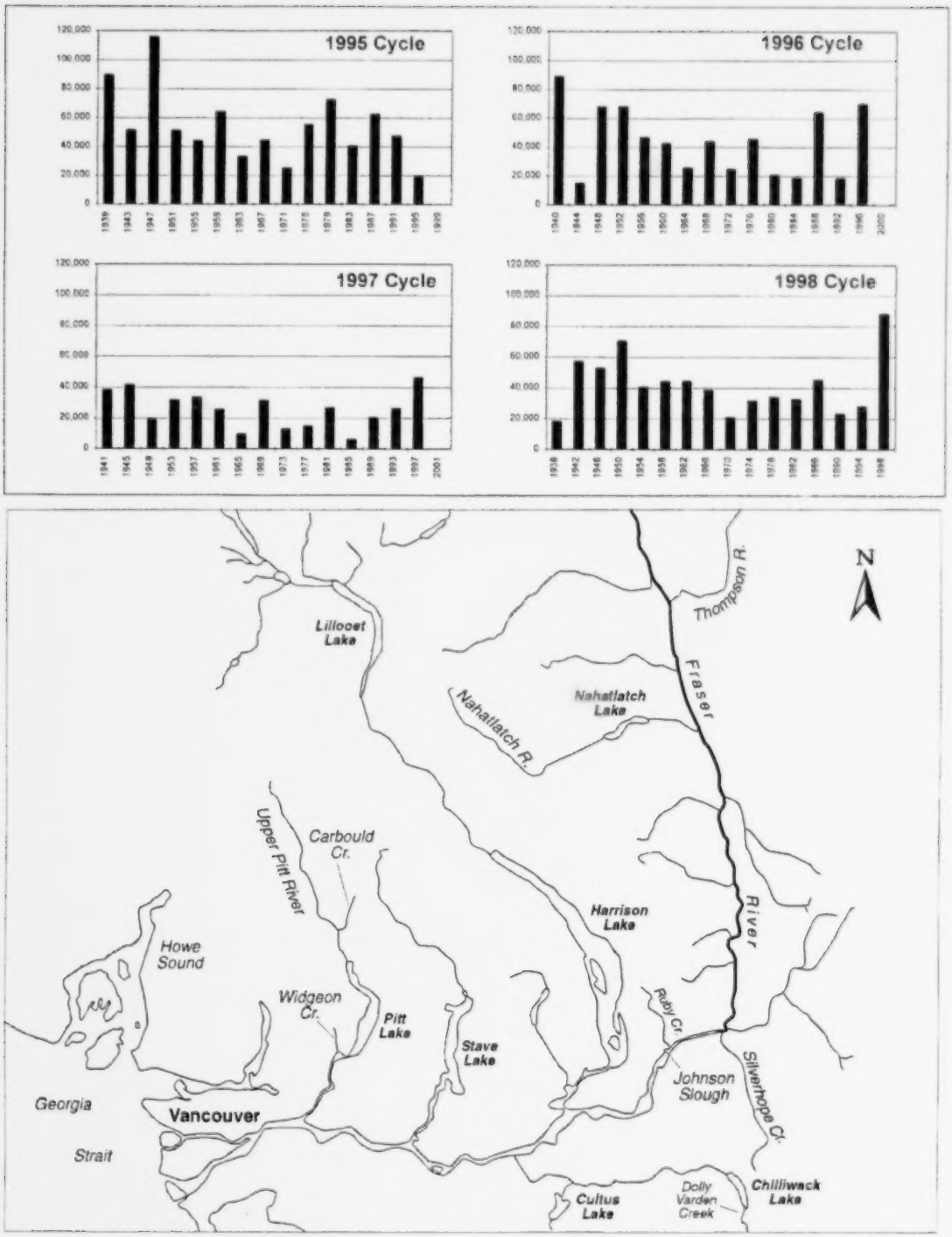


Fig. 4. Adult escapement by cycle and spawning distribution map for Lower Fraser sockeye salmon.

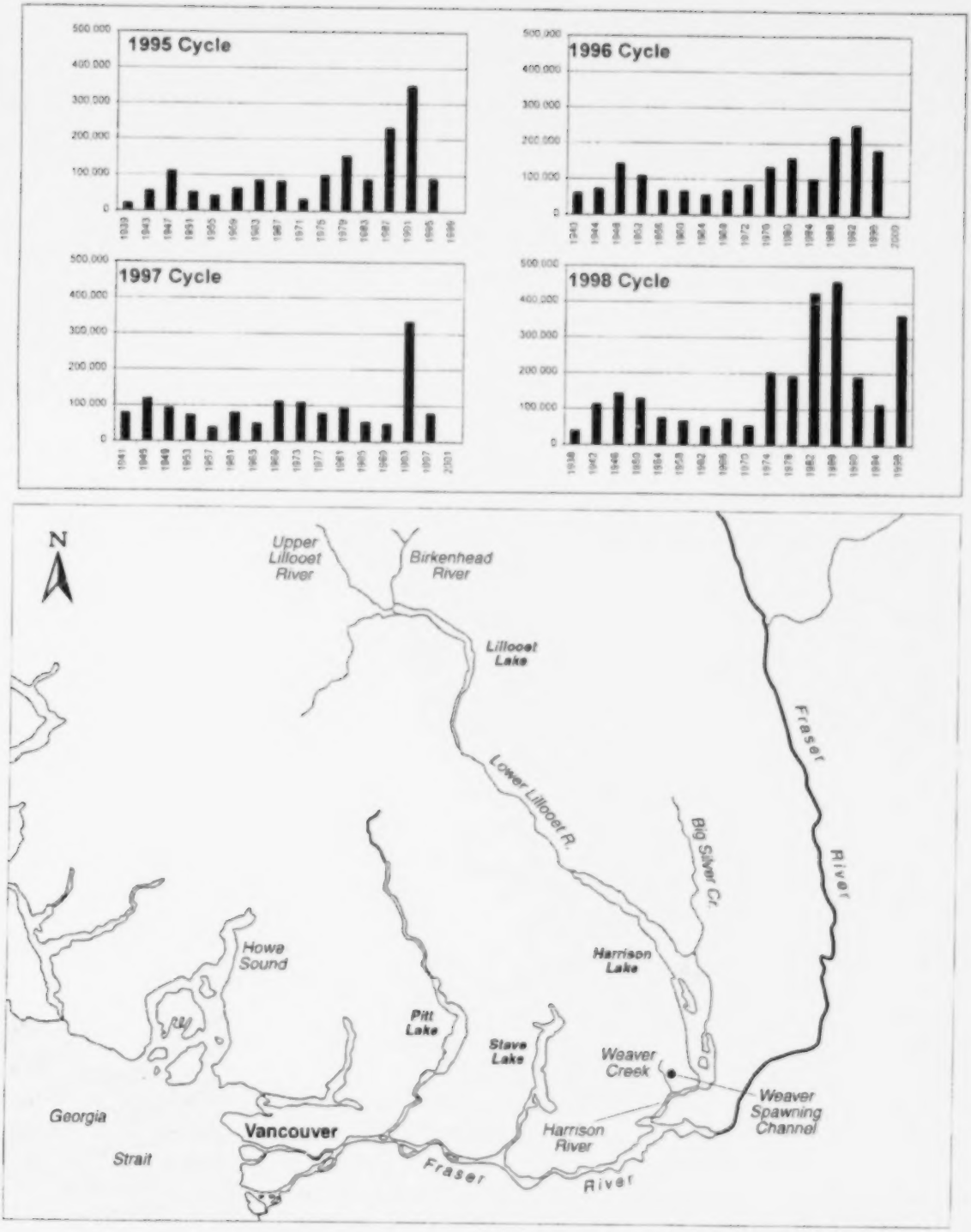


Fig. 5. Adult escapement by cycle and spawning distribution map for Harrison-Lillooet sockeye salmon.

mark-recapture, and Weaver Creek, which was assessed by mark-recapture in the creek and a fence in the channel (Appendix 8). The other stocks were surveyed visually. Survey frequency varied from one in Green River (low water prevented access) to eight in Harrison River (Appendix 10). The latter likely results in an underestimate because observations were confounded by the size and depth of the river and the large co-incident spawning populations of chinook and chum salmon.

The 1998 Harrison-Lillooet group escapement of 364,064 adults and 443 jacks comprises 8% of the Fraser River totals (Table 13). The adult escapement is triple that of the brood year and is the third largest on this cycle since 1938 (Fig. 5). The increase results from the strong escapement of 295,700 to the Birkenhead River, an increase from 39,200 in 1994. In contrast, escapement to Harrison River is half that of 1994. The Weaver System escapement also decreased from the brood year; however, it was intentionally limited using terminal fisheries and does not reflect reduced returns. Spawning success (95%; range 90%-99%) declined from the brood year (99%; range 98%-100%), but exceeded 90% in all stocks (Appendix 11).

The accuracy of the 1998 Harrison-Lillooet escapement estimates depends largely on the Birkenhead and Weaver estimates that comprise 89% of the estimated total escapement. We identify small probable biases in both studies (positive in Birkenhead males, females and Weaver males; negative in Weaver females) (Table 10). We also note that the use of visual surveys in the Harrison River likely introduces a negative bias in that estimate. Assuming random error in the remaining visual estimates, these biases are off-setting to some extent and likely result in a small positive estimation bias for the group.

Seton-Anderson

The Seton-Anderson group consists of one Early Summer Run and one Late Run stock that spawn in Gates and Portage creeks, respectively (Fig. 6). The Gates escapement was estimated at fences in the creek and channel (Appendix 8), while the Portage Creek escapement was estimated from four visual surveys (Appendix 10).

The 1998 Seton-Anderson group escapement of 32,427 adults and 1,503 jacks comprises 1% and 27%, respectively, of the Fraser River total (Table 13). The adult escapement is almost triple the brood year level (Fig. 6). Average spawning success (84%; range 54%-91%) declined from the brood year (average 90%; range 78% to 100%), with particularly poor success in the Gates system (Appendix 11).

The Gates stock was enumerated at a fence and in the spawning channel; consequently, its escapement is likely estimated with only a small negative bias. The use of visual techniques to assess the Portage stock, however, likely introduces a large negative bias (as much as 50%) because abundance was high and the surveys started late. Escapement for this group, therefore, may have a large negative bias.

South Thompson

Early Summer Run: The early South Thompson group consists of 19 stocks that spawn primarily in streams tributary to Shuswap Lake (Fig. 7). The largest stocks on the 1998 dominant cycle spawn in Scotch Creek and Seymour and Eagle rivers. The Scotch escapement (Appendix 7) was estimated at an enumeration fence, while the escapements to Seymour and Eagle rivers were estimated by mark-recapture studies. The latter is the first such study for this stock. The remaining stocks were surveyed visually, with 2-10 surveys per stock (Appendix 10).

The 1998 early South Thompson group escapement of 108,576 adults and 25 jacks comprises 3% and <1%, respectively, of the Fraser River total (Table 13). The adult escapement declined by 48% from the brood year, the second consecutive cycle of significant escapement declines (Fig. 7). Declines are consistent among all of the major stocks in this group. Average spawning success (96%; range 75%-100%) improved from the brood year (94%; range 67%-100%), with particularly high success in the large populations in Eagle and Seymour rivers and Scotch Creek (Appendix 11).

The accuracy of the 1998 South Thompson Early Summer Run escapement estimates depends largely on the Eagle, Scotch and Seymour estimates that comprise 90% of the estimated total escapement. Scotch Creek, counted at a fence, is likely estimated with a small negative bias. For Seymour, our evaluation of sampling biases indicates that the population may be estimated with a small negative bias (Table 10) that is

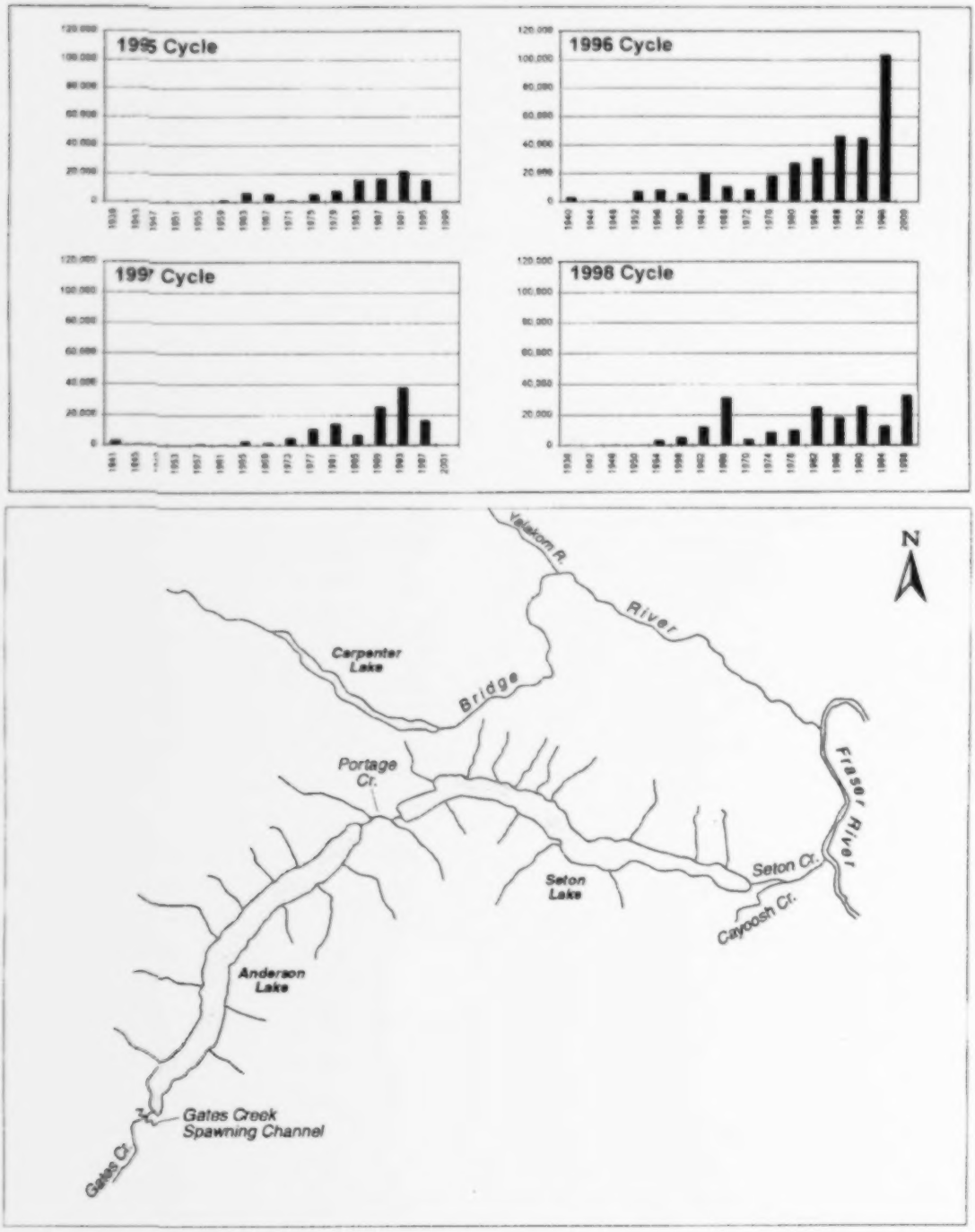
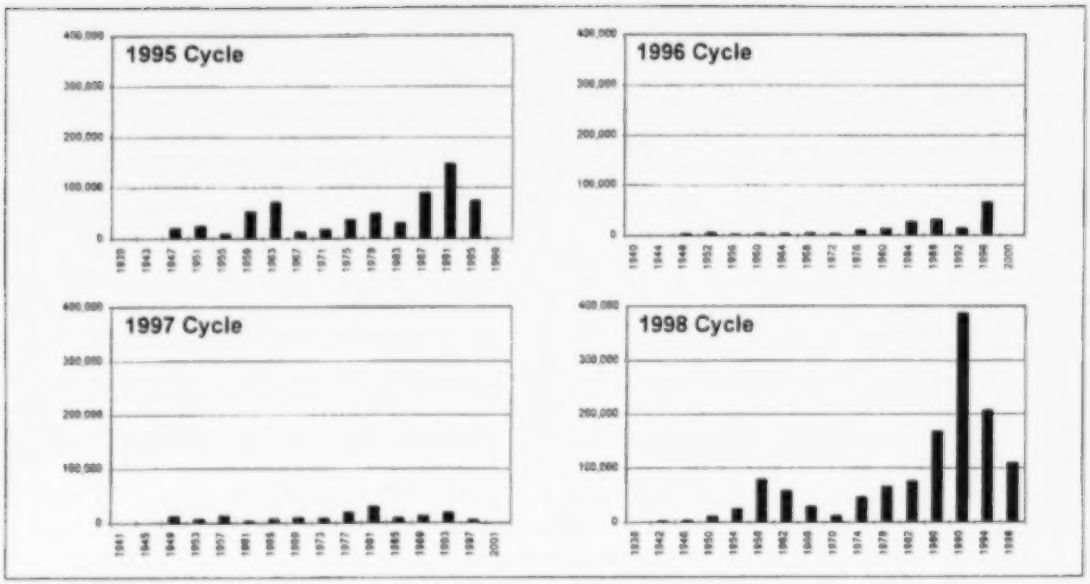


Fig. 6. Adult escapement by cycle and spawning distribution map for Seton-Anderson sockeye salmon.



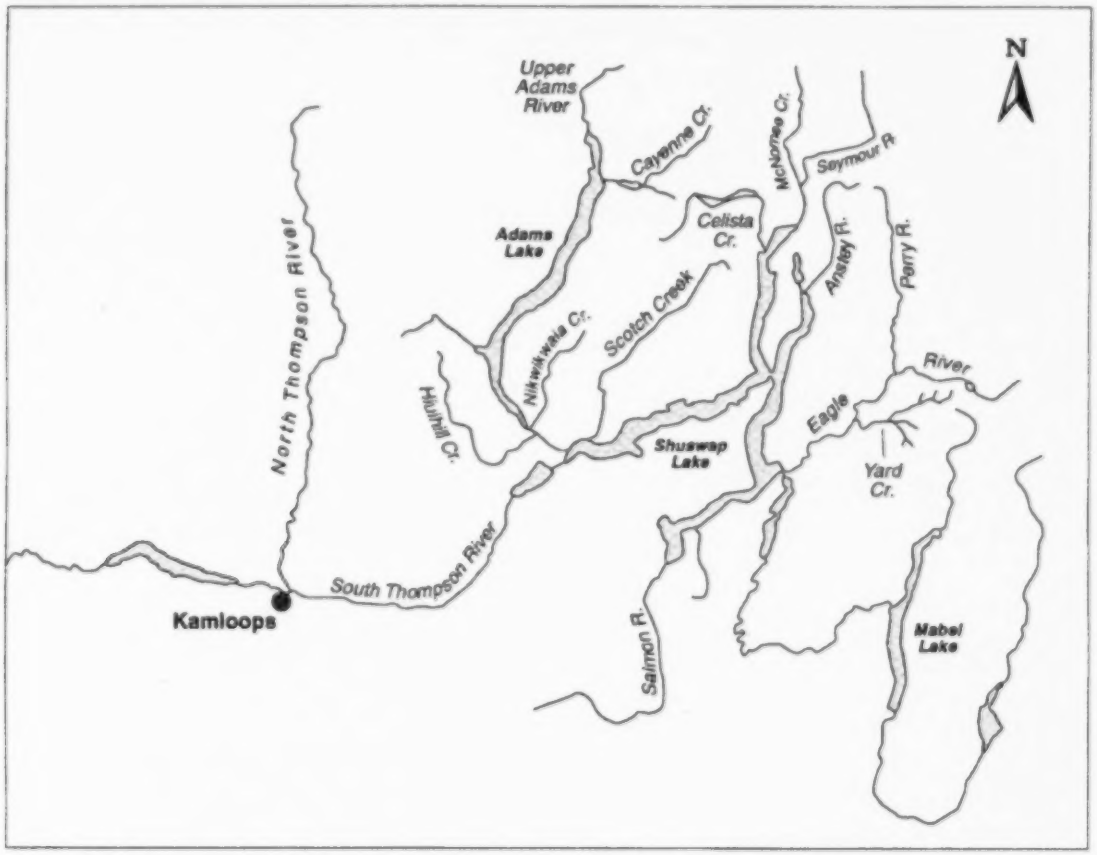


Fig. 7. Adult escapement by cycle and spawning distribution map for South Thompson Early Summer Run sockeye salmon.

unlikely to have exceeded 10%. We are most concerned with the Eagle estimate, where low tag and recovery rates resulted in poor estimation precision and hinder our bias evaluation. We note the possibility of a small positive bias among males. Assuming random error in the remaining visual estimates, the identified biases are offsetting to some extent and likely result in a small negative bias for the group.

Late Run: The late South Thompson consists of 30 stocks that spawn primarily in the lower Adams River area (Adams, Little and South Thompson rivers and Scotch Creek), Adams and Shuswap lake foreshores and tributaries, and the Shuswap River system (Fig. 8). The largest stocks on the 1998 dominant cycle spawn in the lower Adams River area and the Shuswap River; both were assessed by mark-recapture studies. The Eagle River escapement was assessed at a fence (Appendix 7); the remaining stocks were assessed visually, with 2-12 surveys per stock (Appendix 10).

The 1998 late South Thompson escapement of 1,389,271 adults and 312 jacks comprises 31% and 6%, respectively, of the Fraser River total (Table 13). The adult escapement is 1% larger than the brood year, but is one of the smallest on this cycle since 1938 (Fig. 8). The lower Adams River increased from 680,300 in 1994 to 870,900 in 1998, while the Shuswap declined from 399,500 in 1994 to 306,900 in 1998. The latter is the second consecutive cycle of significant escapement declines for this stock. Spawning success (95%; range 83%-100%) declined from the brood year (99%; range 87%-100%), but exceeds 95% among the large populations in the Adams and Shuswap rivers (Appendix 11).

The accuracy of the 1998 South Thompson Late Run escapement estimates depends entirely on the Adams, Little, and Shuswap estimates that comprise 97% of the estimated total escapement. Our evaluation of the Shuswap complex does not identify sampling biases that might bias the population estimate (Table 10). For the Adams complex, however, sampling biases may introduce a positive bias in the female estimate.

North Thompson

The North Thompson group consists of three Early Summer Run stocks that spawn in Fennell and Harper creeks and Raft river (Fig. 9); sockeye were not observed in the North Thompson and Barrier rivers in 1998. The largest stock on the 1998 off-cycle is Fennell Creek. Escapements were estimated visually from six surveys in Fennell Creek and Raft River and two surveys in Harper Creek (Appendix 10).

The 1998 North Thompson group escapement of 15,948 adults and 31 jacks comprises <1% and 1% of the Fraser River total (Table 13). The adult escapement doubled from the 1994 brood year (Fig. 9), largely a result of the increase in Raft River from 1,700 to 7,200. Average spawning success (93%; range 93%-100%) declined from the brood year (98%; range 96%-99%) (Appendix 11).

The North Thompson group was assessed using visual techniques. There are likely random errors of up to ±30% among the individual estimates; however, over and under estimates may off-set to produce a less biased total estimate.

Chilcotin

The Chilcotin group consists of a Summer Run stock that spawns in the Chilko River, Chilko channel, and the north end of Chilko Lake, and three Early Summer Run stocks that spawn in Elkin Creek, Taseko Lake, and the south end of Chilko Lake (Fig. 10). Escapements of the Chilko River and Lake populations were assessed in aggregate by a mark-recapture study; consequently, it is not possible to provide separate estimates for the south lake and north lake and river populations. Elkin Creek and Taseko Lake were assessed visually; the remoteness of the areas, the difficult viewing conditions in Taseko Lake (glacial runoff), and the small expected escapements limited the assessment of these stocks to a single survey (Appendix 10).

The 1998 Chilcotin group escapement of 879,495 adults and 1,934 jacks comprises 20% and 35%, respectively, of the Fraser River total (Table 13). The adult escapement is the largest on this cycle, almost double the 1994 brood year (Fig. 10). Average spawning success (91%; range 91%-92%) declined from the brood year (97%; range 37%-100%) (Appendix 11).

Over 99% of the Chilcotin group escapement was estimated from the Chilko mark-recapture study. Our evaluation of sampling biases indicates that the population may be estimated with a small positive bias (Table 10).

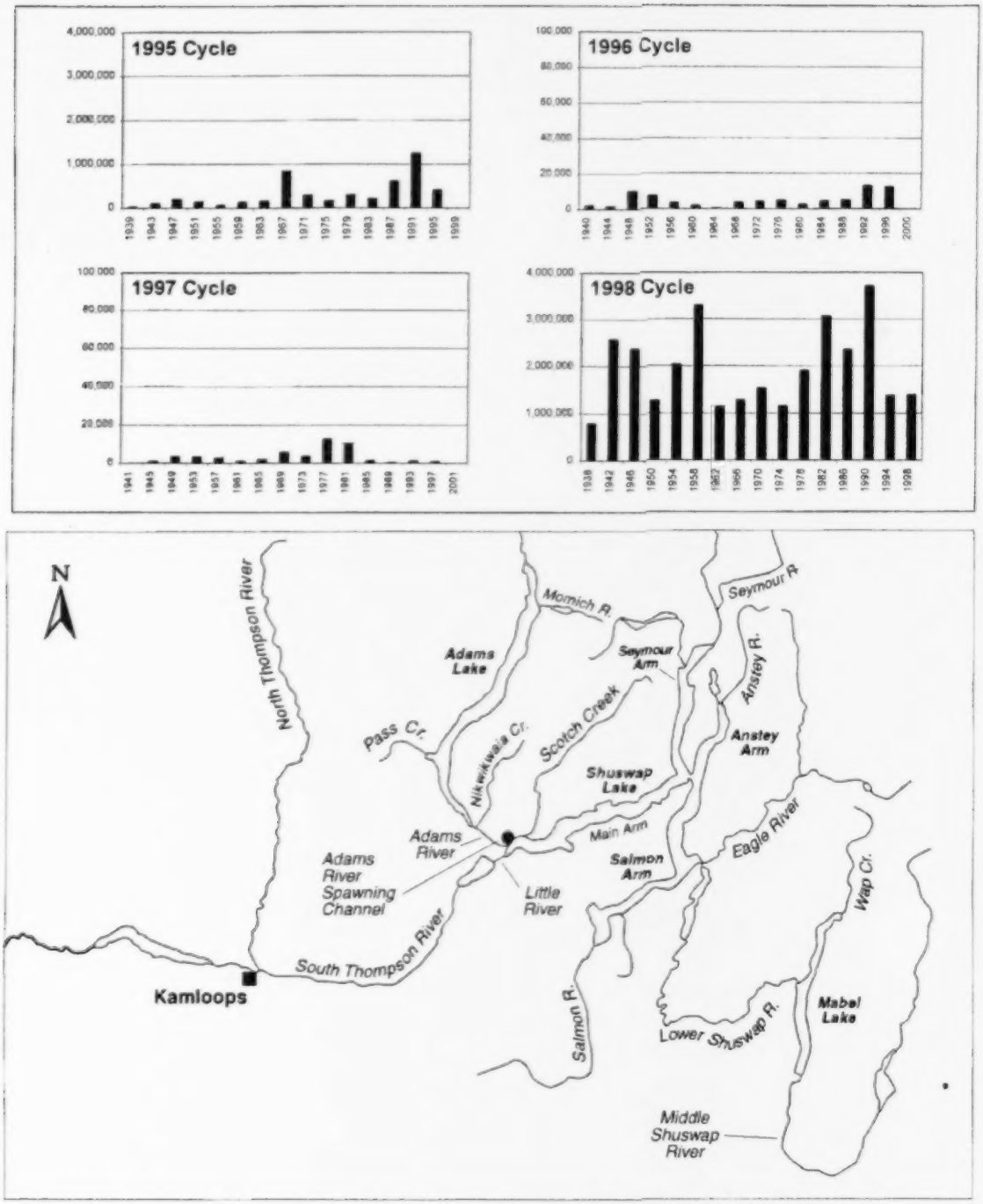


Fig. 8. Adult escapement by cycle and spawning distribution map for South Thompson Late Run sock-eye salmon.

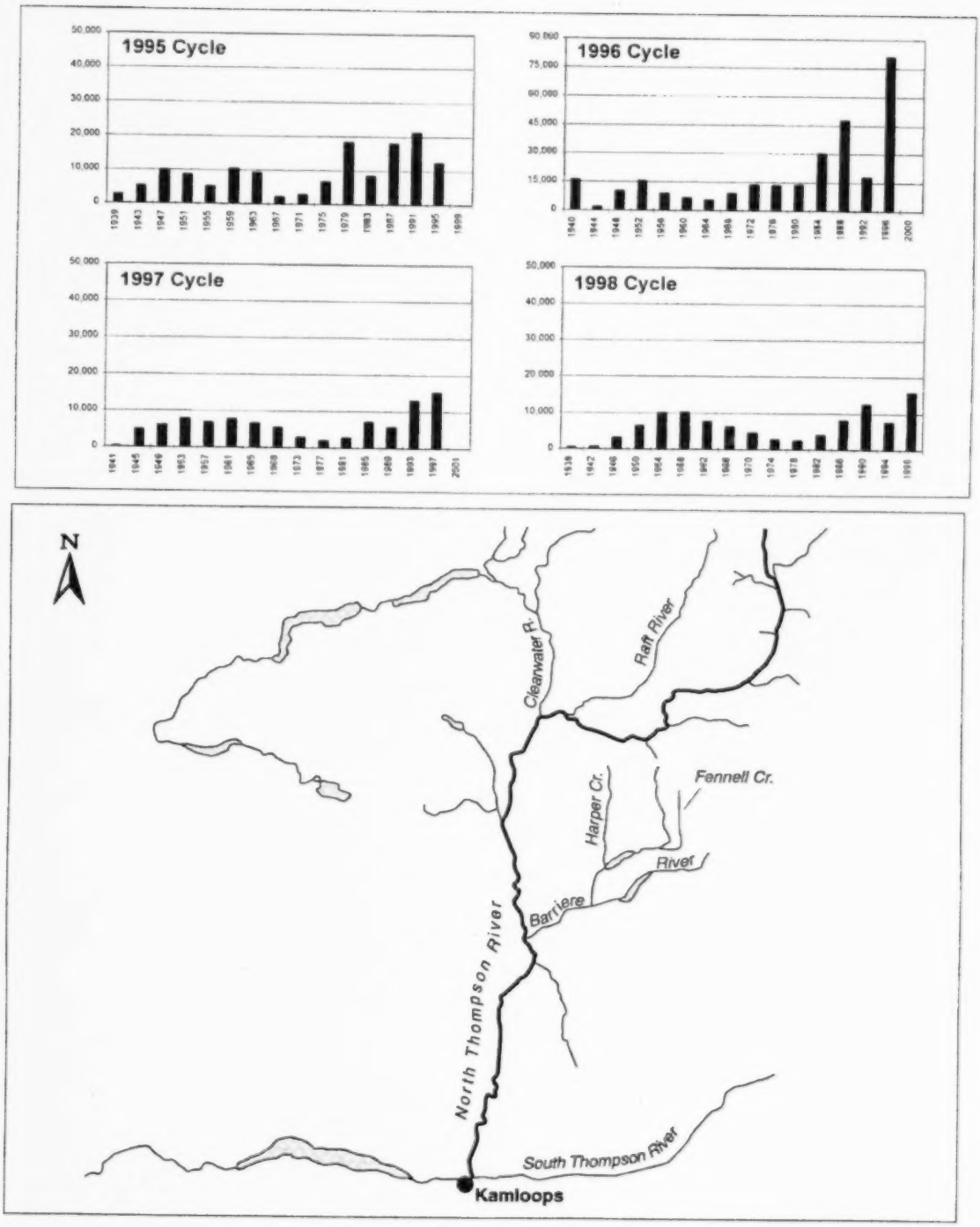


Fig. 9. Adult escapement by cycle and spawning distribution map for North Thompson sockeye salmon.

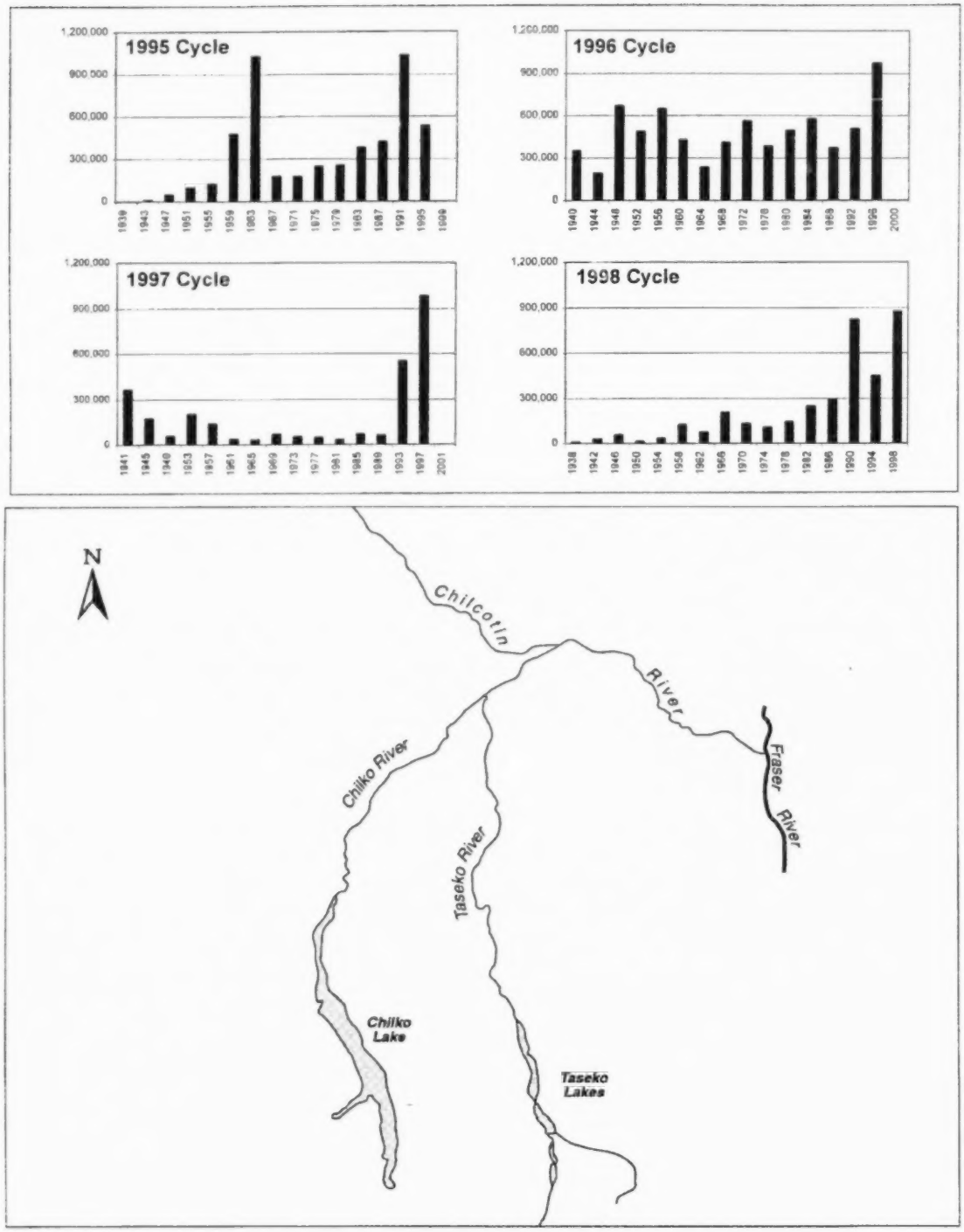


Fig. 10. Sockeye adult escapement by cycle and spawning distribution map for Chilcotin stocks.

Quesnel

The Quesnel group consists of 47 Summer Run stocks that spawn the Horsefly River and Mitchell River systems, in smaller streams tributary to Quesnel Lake, and along the Quesnel Lake foreshore (Fig. 11). The largest stocks on the 1998 subdominant cycle spawn in the Horsefly and Mitchell rivers and McKinley Creek. The two former stocks were assessed using mark-recapture studies; the latter was estimated at an enumeration fence (Appendix 7). The remaining stocks were surveyed visually, with 1-6 surveys per stock (Appendix 10).

The 1998 Quesnel group escapement of 1,179,252 adults (no jacks observed) comprises 27% of the Fraser River total (Table 13). The adult escapement increased by 72% from the record brood year escapement of 686,400. This continues the strong rebuilding trend on the subdominant cycle; the 1998 escapement is the largest ever observed on this cycle and the fifth largest regardless of cycle year (Fig. 11). Escapements are particularly strong in Mitchell River and Quesnel Lake, where they double and triple the brood year levels, respectively. The latter, however, likely reflects a change in survey technique. Since 1994, there has been a concerted effort to identify and assess abundance in previously undocumented spawning areas. Spawning success in the Horsefly (86%), Mitchell (94%) and Quesnel Lake (98%) systems declined from the brood year levels of 99%, 97% and 99%, respectively (Appendix 11).

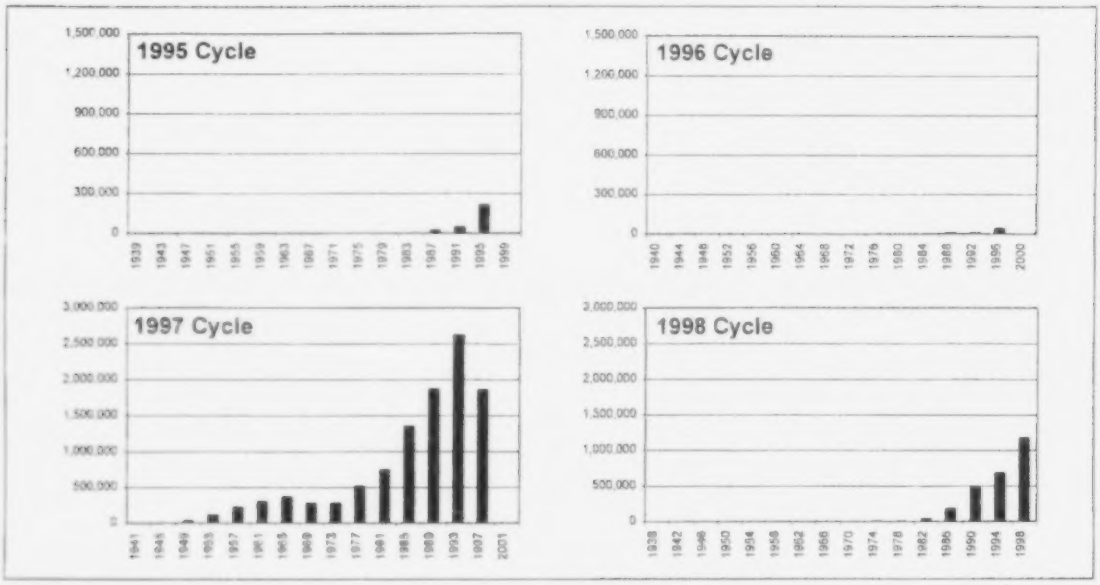
The accuracy of the 1998 Quesnel escapement estimates depends largely on the Horsefly, McKinley and Mitchell estimates that comprise 97% of the total escapement. The McKinley Creek and Horsefly Channel populations were enumerated at the fences and are likely estimated with only a small negative bias. Our evaluation of sampling biases in the Horsefly and Mitchell mark-recapture estimates indicates relatively unbiased studies, although Horsefly and Mitchell males may be estimated with small negative and positive biases, respectively (Table 10). Given the relative sizes of the populations, this may introduce a small negative bias in the over-all group estimate.

Stuart

Early Run: The early Stuart group consists of 38 Early Run stocks that spawn in streams tributary to the Middle River and Takla and Trembleur lakes (Fig. 12). The largest stocks on the 1998 off-cycle spawn in streams tributary to south Takla Lake (Gluske Creek) and Middle River (Forfar, Kynoch and Rossette creeks). Escapements were assessed from visual observations, with 1-14 surveys per stock (Appendix 10). The visual data were calibrated from a comparison of visual observations and fence counts in Forfar, Gluske and Kynoch creeks (Appendix 7).

The 1998 early Stuart group escapement of 32,570 adults and 20 jacks comprises 1% and <1%, respectively, of the Fraser River total (Table 13). The adult escapement increased by 9% from the brood year escapement of 29,800, and is similar to levels reported for most previous cycle years (Fig. 12). Average spawning success (56%; range 0%-100%) declined from the brood year (93%; range 84%-100%) and is by far the lowest ever reported on this cycle (Appendix 11). Consequently, despite a female escapement (15,900) similar to the brood year (15,600), the number of effective females declined from 14,500 to 9,300. This decline is exacerbated by reduced egg fertilization success, which declined from over 90% in 1997 to slightly more than 70% in 1998 (S. MacDonald, pers. comm.). The geographic distribution of the escapement shifted relative to previous cycle years. Relative to the 1994 brood year, the proportion spawning in the Takla System doubled, from 36% (10,700) to 73% (23,800), with the Driftwood System escapement increasing from 1,700 to 11,400, the largest reported on this cycle. Conversely, the proportion spawning in the Middle and Trembleur systems declined, from 45% (13,300) to 18% (5,800) and from 20% (5,900) to 9% (2,900), respectively. This distribution is similar to that observed on the dominant cycle, and may reflect the abnormal predominance of five year old sockeye in the escapement.

The 1998 Stuart early run escapement was assessed using visual surveys that were calibrated inseason within the system. The study design was well executed and likely results in relatively unbiased estimates in the streams tributary to Takla and Trembleur lakes and Middle River. We are concerned, however, that the Driftwood system was assessed using a single helicopter overflight. If the flight did not coincide with peak abundance, a negative bias of up to 8% would be introduced in the total escapement estimate.



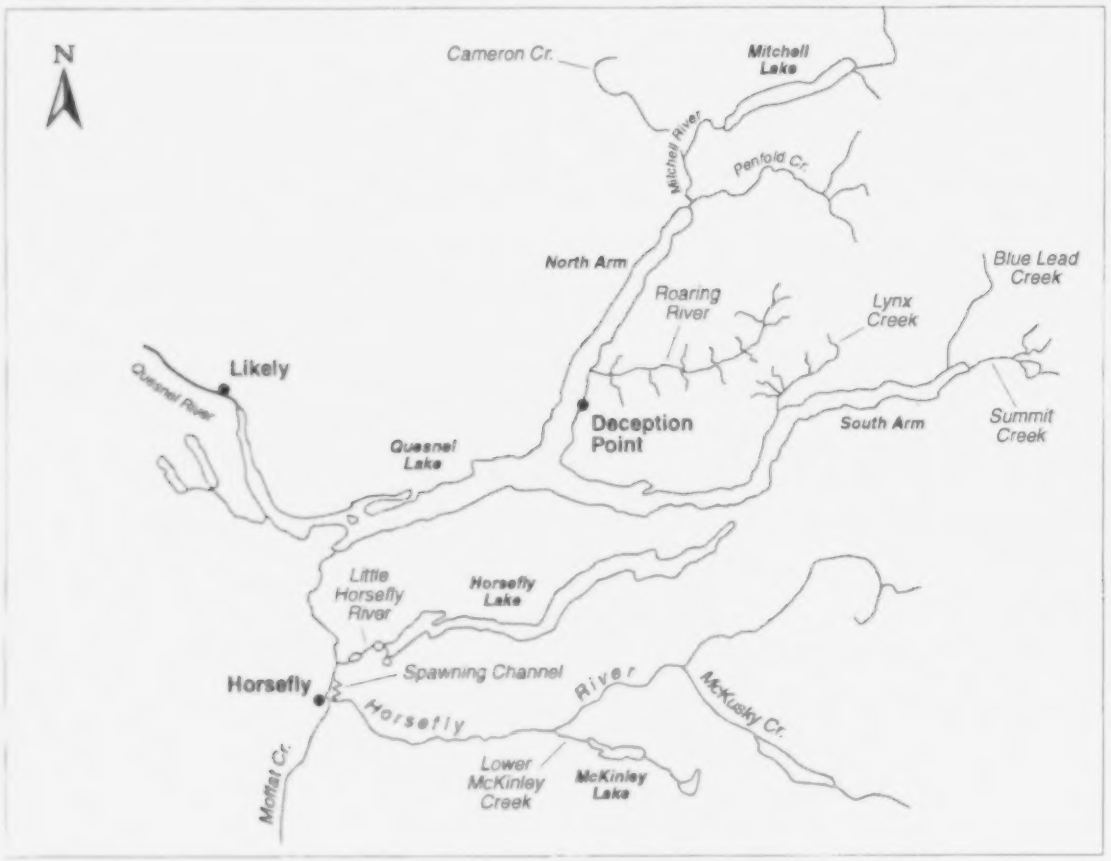


Fig. 11. Sockeye adult escapement by cycle and spawning distribution map for Quesnel stocks.

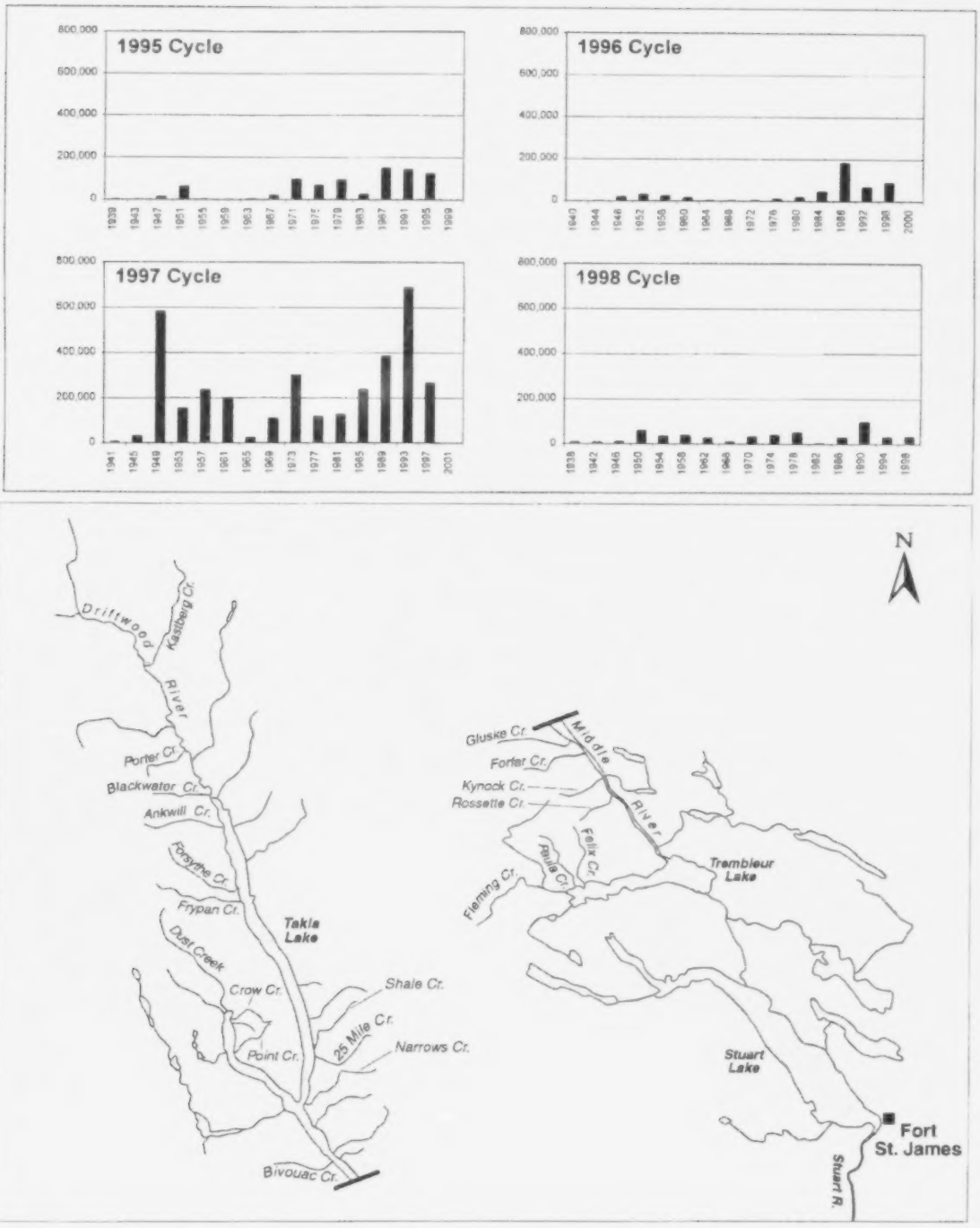


Fig. 12. Sockeye adult escapement by cycle and spawning distribution map for Stuart Early Run sockeye stocks.

Summer Run: The late Stuart group consists of seven stocks that spawn primarily Tachie and Middle rivers, and in several small streams tributary to Takla and Stuart lakes (Fig. 13). The largest stocks on the 1998 subdominant cycle spawn in Tachie and Middle rivers; both were assessed by mark-recapture studies. The Kuzkwa River escapement was assessed using an enumeration fence (Appendix 7), and the remaining stocks were assessed visually, with 3-8 surveys per stock (Appendix 10).

The 1998 late Stuart escapement of 138,397 adults and 1,024 jacks comprises 3% and 18%, respectively, of the Fraser River total (Table 13). The adult escapement increased by 78% and is the second largest reported on this cycle (Fig. 13). The increase largely reflects the Tachie River, where the escapement increased from 42,600 in 1994 to 93,000 in 1998. Average spawning success (98%; range 93%-99%) is unchanged from the brood year (98%; range 95%-100%) (Appendix 11).

Over 95% of the Stuart summer run escapement was estimated by mark-recapture studies in the Middle and Tachie rivers. Our evaluation of sampling biases indicates that, with the exception of a possible small bias among Middle River females, the studies are largely unbiased.

Nechako

The Nechako group consists of a relatively small Early Summer Run (Nadina) and a larger Summer Run (Stellako) stock (Fig. 14). The Stellako was assessed at an enumeration fence (Appendix 7); the Nadina Channel was censused (Appendix 8), and the Nadina River was assessed visually on two surveys (Appendix 10).

The 1998 Nechako group escapement of 189,346 adults and 75 jacks comprises 4% and 1%, respectively, of the Fraser River total (Table 13). The adult escapement increased by 35% (Fig. 14). The Stellako River escapement increased from 138,000 in 1994 to 185,600 in 1998, and is the largest since the record escapement of 245,200 in 1946. Escapement to the Nadina River also increased, from 2,000 in 1994 to 3,700 in 1998. Average spawning success (99%) is similar among stocks and higher than in the brood year (90%) (Appendix 11).

Over 99% of the escapement of this group was enumerated at a fence and in the spawning channel; consequently, its escapement is likely estimated with only a small negative bias.

Upper Fraser

The Upper Fraser group consists of the Bowron River and tributaries (Fig. 15). Although sockeye previously have been observed spawning in the upper Fraser River and Swift Creek (L. W. Kalnin, DFO technician, pers. comm.), there is no evidence of sustained production from those areas. In 1998, the Bowron River was assessed visually on one helicopter flight (Appendix 10); the upper Bowron River was also assessed on one boat survey.

The 1998 Upper Fraser group escapement of 4,751 adults and 26 jacks comprises <1% and 1%, respectively, of the Fraser River total (Table 13). The adult escapement increased by 8% from the 1994 brood year escapement of 4,400 (Fig. 15). Average spawning success (100%) is identical to the brood year.

The Upper Fraser group was assessed using visual techniques, with a possible estimation error of up to ±30%.

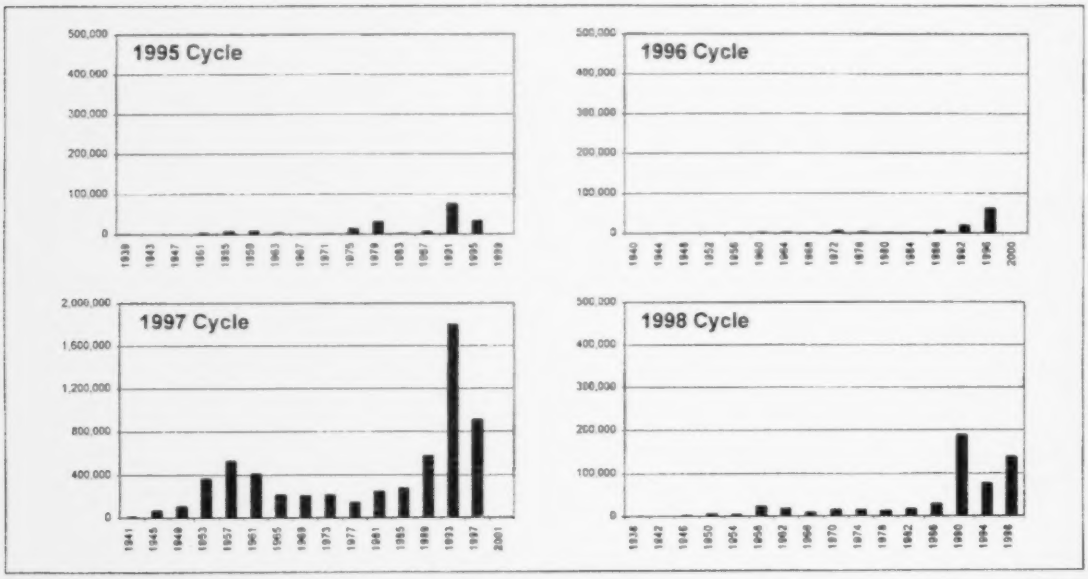
RUN TIMING GROUP

Early Run

The Early Run consists of 38 stocks that spawn in the Stuart River system (Fig. 12). The largest stocks on the 1998 off-cycle typically spawn in streams tributary to south Takla Lake (Gluske Creek) and Middle River (Forfar, Kynoch and Rossette creeks). Escapements were estimated from enumeration fences in Forfar, Gluske and Kynoch creeks (Appendix 7) and visual surveys conducted in all streams every 1-14 days (Appendix 10). Escapement is estimated from the relationship between the visual data and the known escapement in the fenced streams. The 1998 escapements are reported in the *Stuart Early Run* section of this report and will not be repeated here.

Early Summer Run

The Early Summer Run consists of 32 stocks that spawn throughout the Fraser River system. These stocks migrate through the lower Fraser River from mid July to mid August and spawn from late August to mid September. The largest stocks on the 1998 cycle are the upper Pitt River in the



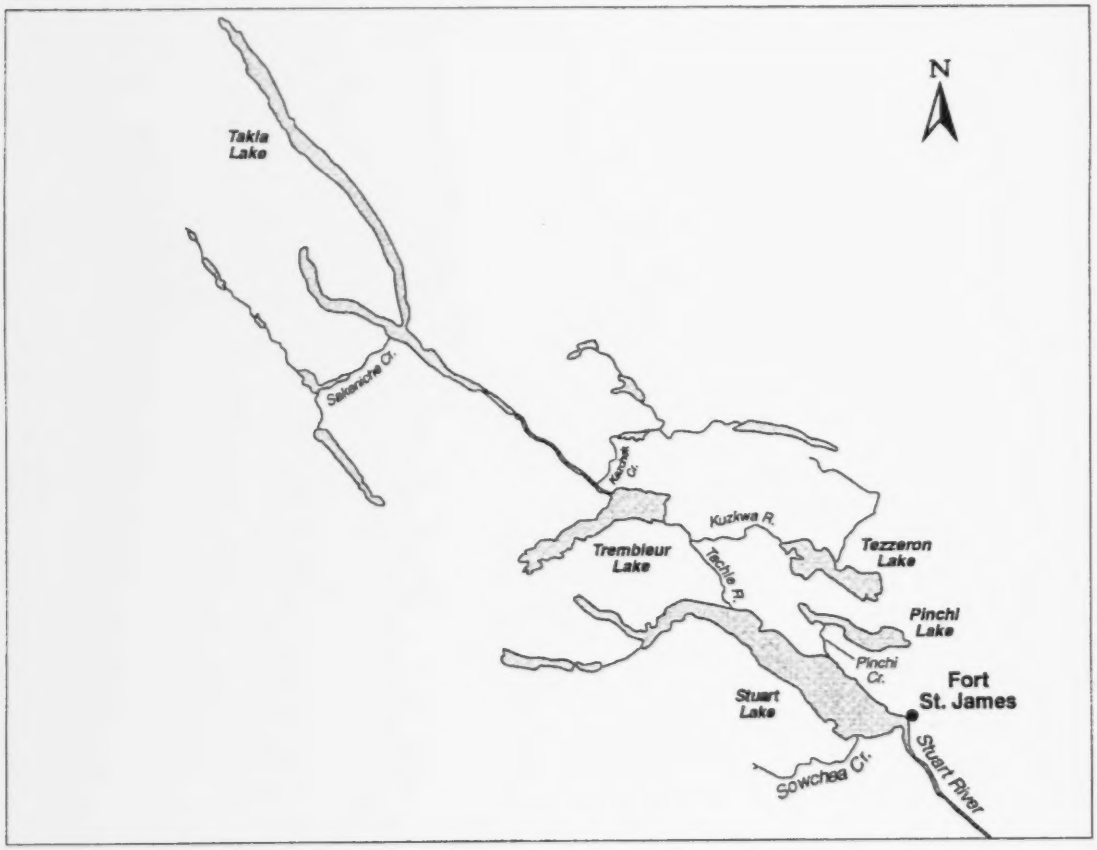


Fig. 13. Sockeye adult escapement by cycle and spawning distribution map for Stuart Summer Run sockeye stocks.

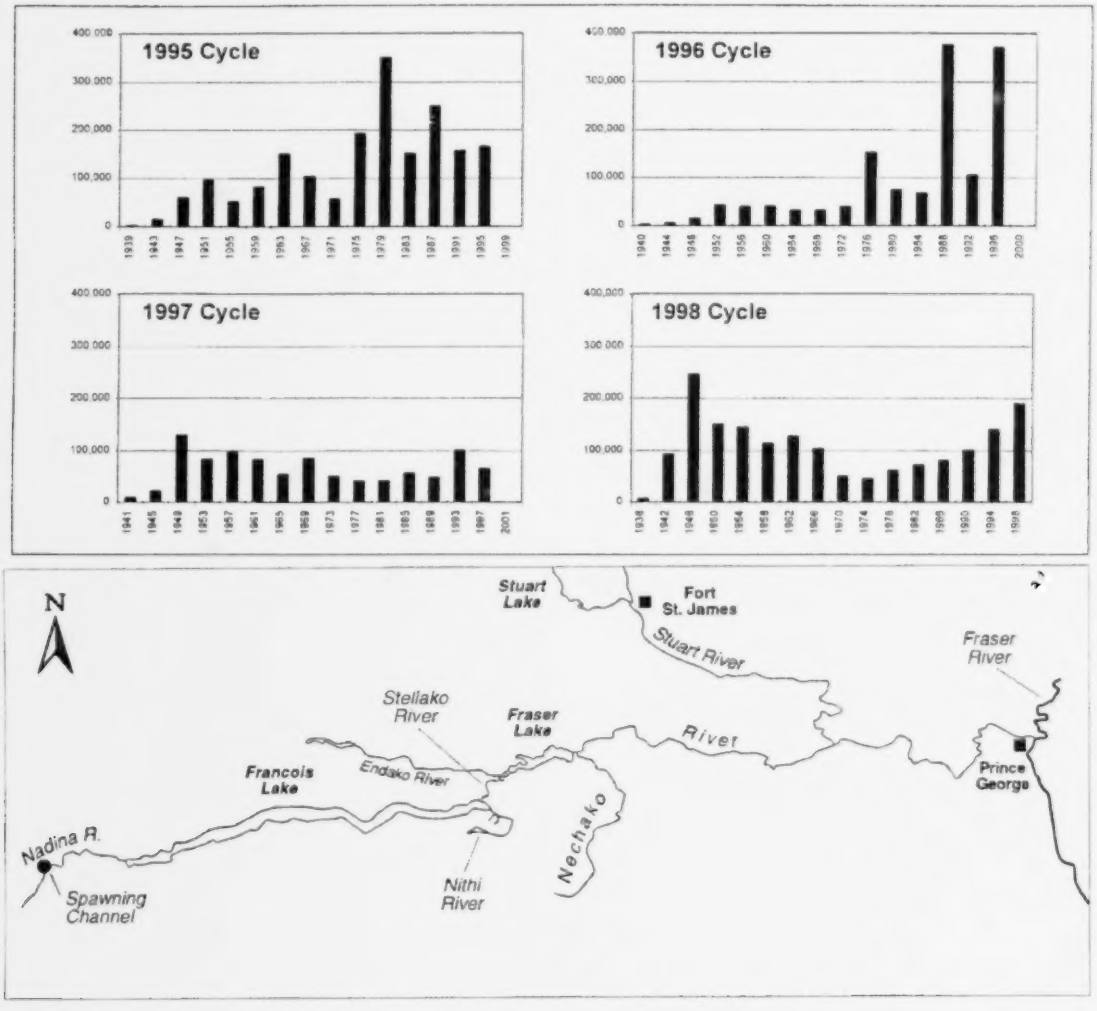


Fig. 14. Adult escapement by cycle and spawning distribution map for Nechako sockeye salmon

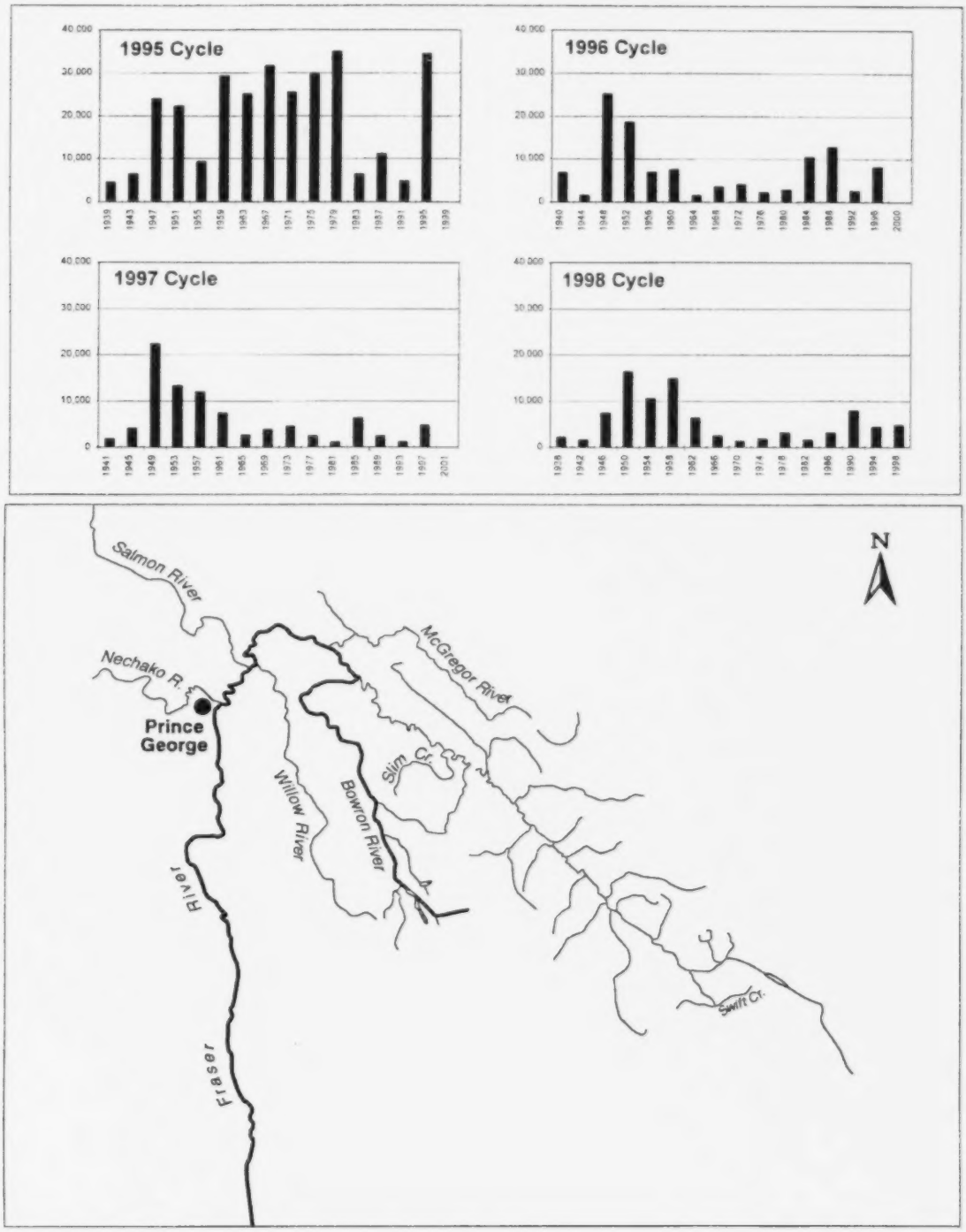


Fig. 15. Adult escapement by cycle and spawning distribution map for Upper Fraser sockeye salmon.

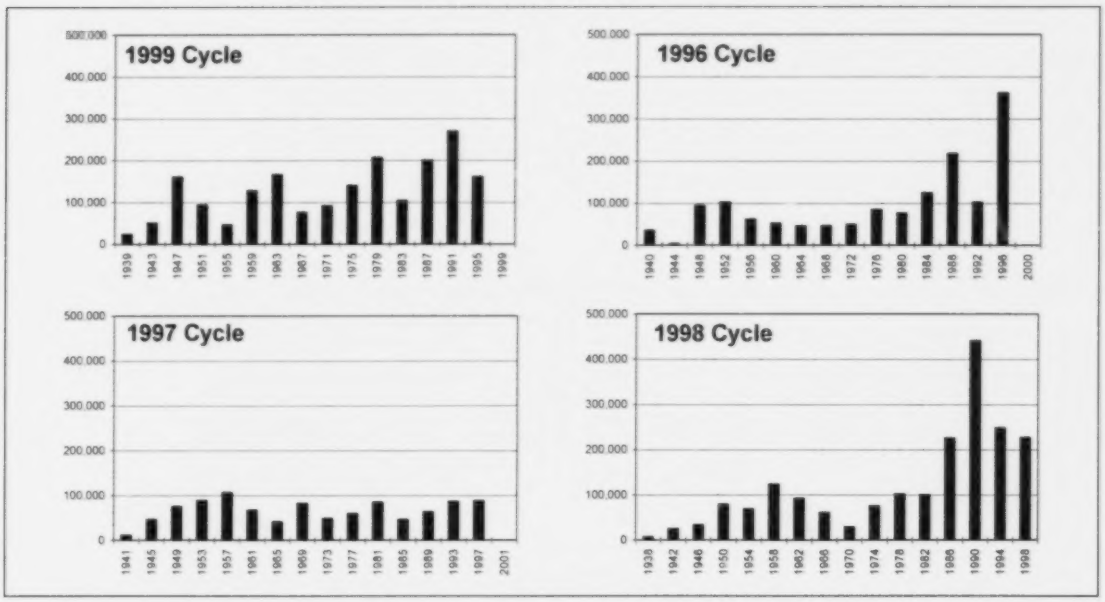


Fig. 16. Adult escapement by cycle for Early Summer Run Fraser River sockeye salmon.

Lower Fraser group, Gates in the Seton-Anderson group, Eagle and Seymour rivers and Scotch Creek in the South Thompson group, and Fennell Creek and Raft River in the North Thompson group. The escapement of all of the largest stocks except those in the North Thompson were estimated using either enumeration fences or mark-recapture studies; the escapement of the North Thompson and other stocks of were estimated visually.

The 1998 Early Summer Run escapement of 226,662 adults and 1,582 jacks comprises 5% and 28%, respectively, of the Fraser River total (Appendix 11). Adult escapement declined by 10% from the brood year escapement and is well below the record 1990 escapement on this cycle of 441,000 (Fig. 16); however, the escapement is the third largest on the cycle. Relative to the 1994 brood year, adult sockeye escapements increased in all areas except the South Thompson: in the Lower Fraser area, the upper Pitt River escapement (76,900) is the largest on this cycle and comprises 34% of the Early Summer Run total; in the Seton-Anderson area, the Gates escapement increased from 3,400 to 7,200; in the North Thompson area, the total escapement (15,900) is the largest on this cycle; in the Nechako area, the Nadina escapement increased from 2,000 to 3,700; and in the Upper Fraser area, the Bowron escapement increased from 4,400 to 4,800. In contrast, escapement declined by 49% among the large dominant-cycle South Thompson stocks: the Scotch Creek escapement declined from 73,200 to 36,000; the Seymour River escapement declined from 56,200 to 33,400; and the Eagle River escapement declined from 45,500 to 28,500. Spawning success averages 94% in 1998, ranging from 61% in the Gates system (where spawning success is frequently low) to up to 100% among several other stocks (Appendix 11). This is near the upper end of the range of spawning success levels for this cycle; it occurred despite the adverse *en route* and spawning ground conditions that were reported for many of these populations. Water levels on all spawning grounds were low throughout the spawning period, obstructing access to many small creeks; extreme examples are in Ross and Onyx creeks, which remained dry through the spawning period. Water temperatures on the spawning grounds tended to be higher than normal, but not consistently so among all Early Summer Run stocks. For example, temperatures approached or exceeded 20° C in Chilliwack Lake, lower Adams, Momich, Seymour, and Raft rivers and Scotch Creek, while they typically remained below 15° C in the upper Pitt, upper Adams and Eagle rivers and Cayenne Creek.

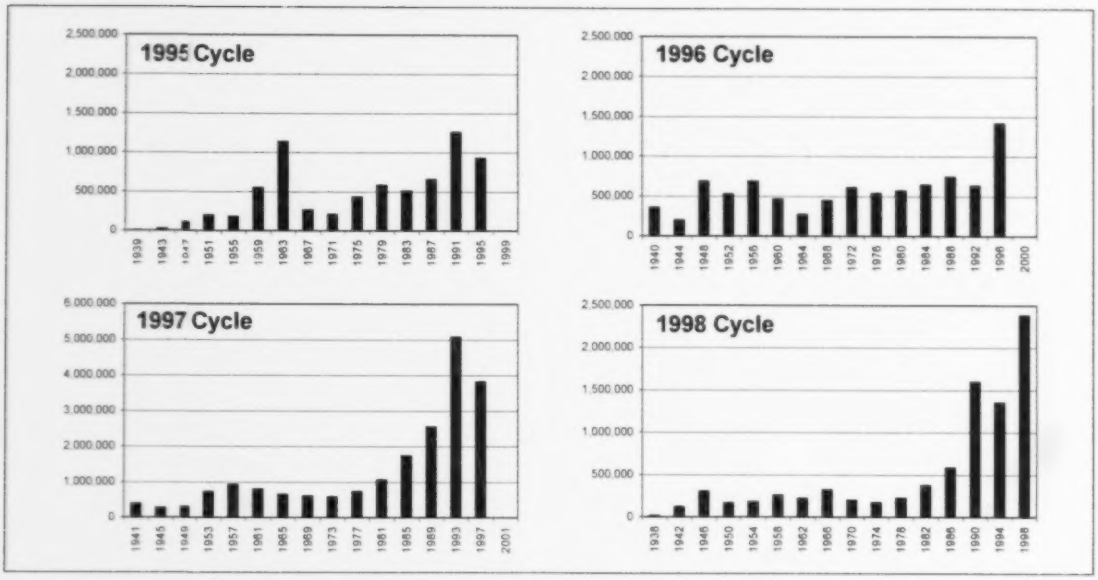


Fig. 17. Adult escapement by cycle for Summer Run Fraser River sockeye salmon.

The escapement of the Early Summer Run was intensively assessed in 1998, with mark-recapture studies on the Pitt, Eagle and Seymour rivers (61% of the estimated escapement), enumeration fences on Gates and Scotch creeks (16%), and channel counts at Gates and Nadina (5%). Assuming random error in the remaining visual estimates, the overall accuracy of the Early Summer Run group depends on the mark-recapture studies. Our evaluation of sampling biases suggests there is a potential for negative biases in the estimates for Pitt females, and Seymour males and females, and positive biases in the estimate for Eagle males (Table 10). Consequently, there is likely a small negative bias in the total escapement estimate for this group.

Summer Run

The Summer Run consists of 57 stocks that spawn in the Chilcotin, Quesnel, Nechako and Stuart systems (Fig. 1). The escapement of the major stocks was estimated using either mark-recapture studies (Chilko, Horsefly, Mitchell, Tachie and Middle rivers) or enumeration fences (Stellako and Kuzkwa rivers and MacKinley Creek). The smaller stocks, such as Quesnel Lake foreshore and tributary spawners, were assessed visually.

The 1998 Summer Run escapement of 2,382,300 adults and 3,014 jacks comprises 54% and 53%, respectively, of the Fraser River total (Appendix 11). Adult escapements increased by 76% from the brood year escapement of 1,351,600 (Fig. 17); it is the largest escapement reported on this cycle, and the fourth largest on any cycle since 1938. Relative to the 1994 brood year, adult escapements increased in all four systems: from 451,000 to 879,500 in the Chilko System; from 686,400 to 1,179,300 in the Quesnel System; from 76,500 to 138,400 in the Stuart System; and from 138,000 to 185,600 in Stellako River. The escapements to the Chilcotin and Quesnel are records on this cycle, while the escapements to the Stellako and Stuart are the second largest on this cycle. Spawning success for Summer Run sockeye averages 91%, slightly below the long-term average of 93% on this cycle. Among the major stocks, success ranges from 75% in McKinley Creek to 99% in Middle and Stellako rivers, and tends to be lower among mid-Fraser (91% in Chilko; 89% in Quesnel) compared to upper Fraser (99% in Stellako; 98% in Stuart) stocks. Physical conditions in the natal areas generally reflect the unusually hot, dry weather. Water levels tended to be low throughout the spawning period, obstructing access to some smaller creeks (*e.g.*, Killdog, Devoe, Isaiah, Long, Sue, Trickle and Hazeltine creeks). Spawning ground water temperatures tended to be higher than normal, but not consistently so among all Summer Run stocks. For example,

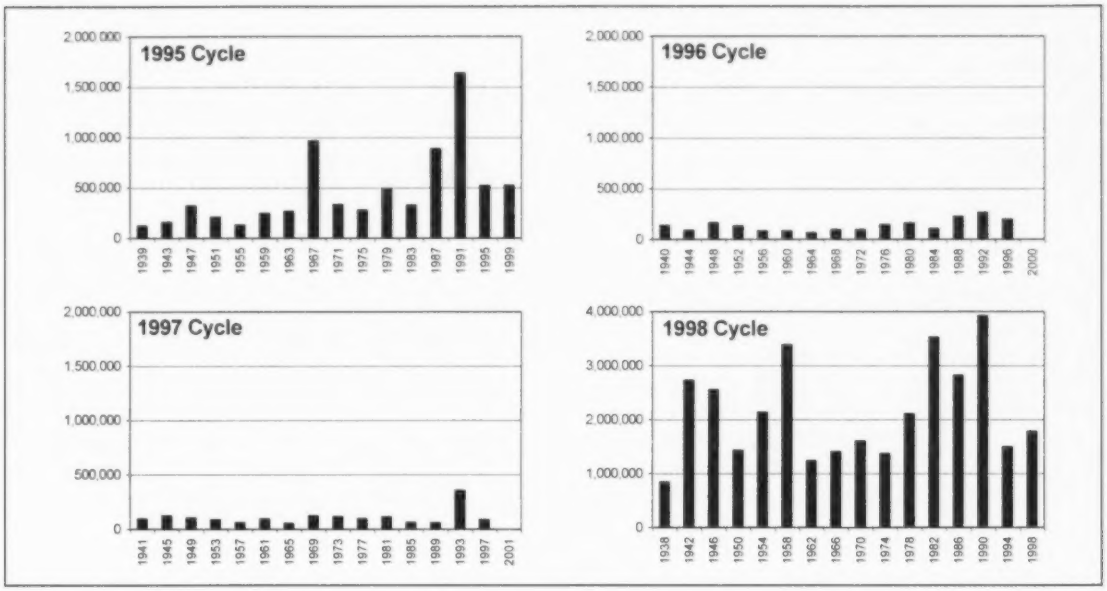


Figure 18. Adult escapement by cycle for Late Run Fraser River sockeye salmon.

temperatures approached or exceeded 20° C in Horsefly and Stellako rivers and McKinley Creek, while they typically remained below 15° C in the Chilko, Mitchell, Tachie and Middle rivers. Chilko River flows and temperatures were anomalous among the Summer Run stocks; high flows and low temperatures reflect the increased glacial melt that resulted from the hot weather.

The escapement of Summer Run sockeye was intensively assessed in 1998, with mark-recapture studies on the Chilko, Horsefly, Mitchell, Middle and Tachie rivers (86% of the estimated escapement), enumeration fences on McKinley Creek and Stellako and Kuzkwa rivers (11%), and channel counts at Horsefly (1%). The overall accuracy of the Summer Run estimate again depends on the mark-recapture studies. Our evaluation of sampling biases suggests there is a potential for negative biases in the estimates for Horsefly males, and positive biases in the estimate for Chilko males and females, Mitchell males and Middle females (Table 10). Consequently, there is likely a positive bias in the total escapement estimate for this group.

Late Run

The Late Run consists of 52 stocks that spawn in the Lower Fraser, Harrison-Lillooet, Seton-Anderson and South Thompson areas. The largest stocks on the 1998 cycle are in Birkenhead River and Weaver Creek in the Harrison-Lillooet group, Portage Creek in the Seton-Anderson group, and lower Adams, Little, and lower and middle Shuswap rivers in the South Thompson group. With the exception of Portage Creek, the escapements of the largest stocks were assessed by either enumeration fences or mark-recapture studies; the escapements of the remaining stocks were estimated visually.

The Late Run escapement of 1,780,543 adults and 988 jacks comprises 40% and 18%, respectively, of the Fraser River total (Appendix 11). The adult escapement increased by 19% from the brood year escapement of 1,499,000 (Fig. 18). The adult escapement is only the ninth largest on this or any cycle since 1938; the jack escapement is the second smallest on this cycle since 1938, continuing the long-term decline among jack populations. Relative to the brood year, adult escapements increased in three of the four geographic groups: from 114,400 to 364,100 in the Harrison-Lillooet; from 9,300 to 25,200 in the Seton-Anderson; and from 1,370,700 to 1,389,300 in the South Thompson. Only the adult escapement in the Lower Fraser declined, from 4,600 to 2,000, continuing the long-term decline for this group. Spawning success averages 97% in 1998, slightly above long-term average of 95% on this cycle. Among the

major stocks, spawning success ranges from 91% in Weaver and Portage creeks to 96% in Adams River. Physical conditions in the natal areas were generally good; only the Adams River and a few smaller streams exceeded 15° C for extended periods.

The escapement of Late Run sockeye was also intensively assessed, with mark-recapture studies on Birkenhead, Weaver, Adams, Little, and Shuswap rivers (95% of the estimated escapement), enumeration fences on Sweltzer, Eagle and Salmon rivers (1%), and channel counts at Weaver (2%). The accuracy of the Late Run estimate again depends on the mark-recapture studies. Our evaluation of sampling biases suggests there is a potential for negative bias in the estimate for Weaver females, and positive biases in the estimates for Birkenhead males and females, Weaver males, and Adams females (Table 10). While the potential biases off-set each other to some extent, the relative size of the Adams and Birkenhead escapements indicates there is likely a positive bias in the total escapement estimate for this group.

CONCLUSIONS

1. Estimation Biases: It is not possible to quantify the magnitude of bias (*i.e.* the accuracy) of the 1998 Fraser River sockeye escapement estimates. Instead, we focus on identifying probable biases in each of the survey techniques in order to provide a qualitative estimate of the direction of the overall bias in the estimates for specific populations as well as geographic and run timing aggregates. We note that understanding the potential biases in the mark-recapture technique is critical because it is used to estimate a large proportion of the total system-wide escapement. New study designs and improved study design execution have substantially reduced biases. New analytic tools, including complementary two-sample stratifications to investigate bias, have also improved the reliability of the technique; however, the approach needs refinement to make it study-specific and to permit the quantification of results.

2. Mark-Recapture Studies: We use a three step process to evaluate potential bias in the mark-recapture estimates; an evaluation of: a) study design execution; b) biases in complementary two-sample data stratifications; and c) differences in the maximum likelihood Darroch and pooled Petersen estimates. In our evaluation of (a), we conclude that the studies were well designed and executed in 1998 and incorporated substantial improvements over recent years. Despite deficiencies in the Eagle and Pitt studies, there were no overall problems in the implementation of the studies that are likely to introduce serious bias in the overall estimates.

In our evaluation of (b), we note the potential for bi-directional (both positive and negative) biases in the population estimates. This is inconsistent with the traditional bias structure in mark-recapture studies where positive biases are common. Evidence from the Stellako River study indicates that positive biases likely result from a decreasing probability of tagging with distance upstream coupled with a complementary increasing probability of recovery. We conclude that study design changes since 1994 that make tag incidence spatially more representative have changed the bias structure of the estimates. This has important implications to the overall bias structure of the annual management-assessment process.

In our evaluation of (c), we conclude that a comparison of MLE and PPE estimates provides an indication of the direction of possible error in the PPE but overstates its magnitude. We further conclude that the magnitude of the bias in the mark-recapture studies is not quantifiable but, because the biases across studies are bi-directional, their overall magnitude is likely to be small. Because mark-recapture studies were used to estimate 87% of the escapement, bias in the total escapement is also likely to be small.

3. Enumeration Fences and Visual Surveys: Potential biases in the estimates generated from the enumeration fences and visual surveys are small. The enumeration fence studies were well executed and provide estimates of population size that are unlikely to have negative biases as large as 5%. Similarly, while the individual visual survey estimates are prone to errors of ±30%, central tendency among a wide range of positive and negative errors in the 144 estimates is likely to limit the overall biases in total. The exceptions are the Driftwood, Portage, Harrison and South Thompson, where inadequate study designs or poor survey conditions are likely to result in substantial underestimates. We note, however, that the likely impact of these biases is small given that

only 4% of the escapement is estimated using this technique.

5. Stress Effects: Despite record high water temperatures on the migratory route and in some natal areas, we do not identify a clear pattern of stress effects in any population with the exception of the early Stuart, a population that undertook one of the longest riverine migrations at a time when the temperature deviations from normal were greatest. While we acknowledge that *en route* conditions certainly resulted in physiological stress and mortality in other populations, we conclude that these conditions are unlikely to have changed the behaviour of the fish that were able to reach the spawning grounds to an extent that would introduce significant biases in the population estimates.

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Crew members for the 1998 sockeye studies included: T. Abbott, L. Anderson, R. Armstrong, P. Arnouse, L. Beron, C. Bland, M. Bloudell, O. Brockwell Jr., C. Brooks, S. Brown, L. Candall, W. Chandler, M. Chimenti, E. Cohen, W. Dale, L. Davidson, B.Davis, C. Elwick, J. Evans, T. Ewanyshyn, S. Fancy, J. Gagnon, A. Gignac, K. Gray, E. Hansen, W. Harbridge, D. Hicks, C. Huska, P. Janos, S. Janzen, R. Joseph, D. Jarvis, N. John, C. Kirkpatrick, D. Klassen, R. Lapointe, W. Leveque, C. Locke, D. MacDonald, R. McBurney, M. McIntyre, M. McMyn, J. Mahoney, J. Mann, S. Markin, H. Melnichuk, J. Meyers, H. Moore, L. Myer, H. Narcisse, A. Nelson, J. Paddison, T. Pariler, C. Parken, D. Pearson, J. Peters, T. Peterson, L. Philpot, M. Prevost, H. Pulvermacher, B. Qudman, J. Raume, L. Richie, C. Ridley, E. Robinson, B. Sampogna, T. Smith, B. Solonas, R. Tadey, N. Vivian, T. Welch, F. Wells, J. Wideman, K. Wiebe, C. Williams, G. Witzky, M. Wyeth, and B. Zisserson. Data entry and preliminary analyses were conducted by K. Benner, B. Klassen and G. Schuler.

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APPENDICES

Appendix 1. Results of statistical tests for sampling bias in Fraser River sockeye mark-recapture studies, 1995-1998. *Bias* indicates a significant chi-square test result ($p < 0.05$), except Kolmogorov-Smirnov 2-sample test used for size.

		1995		1996		1997		1998	
Study	Test type	Male	Female	Male	Female	Male	Female	Male	Female
Pitt	*Application*	-	-	No bias	No bias	Bias	Bias	No bias	Bias
	Temporal	-	-	Bias	Bias	No bias	No bias	No bias	Bias
	Spatial	-	-	Bias	Bias	No bias	No bias	No bias	No bias
	Sex	-	-						
	Recovery								
	Temporal	-	-	Bias	Bias	No bias	Bias	No bias	Bias
	Spatial	-	-	Bias	Bias	No bias	Bias	?	?
	Sex	-	-	No bias	No bias	No bias	No bias	No bias	No bias
	Size	-	-	Bias	Bias	No bias	Bias	No bias	Bias
Birkenhead	*Application*								
	Temporal	Bias	Bias	Bias	Bias	No bias	No bias	Bias	Bias
	Spatial	Bias	Bias	Bias	Bias	No bias	No bias	No bias	Bias
	Sex	No bias	Bias	No bias	No bias	No bias	No bias	No bias	No bias
	Recovery								
	Temporal	Bias	No bias	Bias	Bias	No bias	No bias	No bias	No bias
	Spatial	No bias	No bias	No bias	No bias	No bias	No bias	Bias	No bias
	Sex	No bias	Bias	Bias	Bias	No bias	No bias	Bias	No bias
	Size	Bias	No bias	Bias	No bias	No bias	Bias	No bias	No bias
Weaver	*Application*								
	Temporal	-	-	n/a	n/a	-	-	Bias	Bias
	Spatial	-	-	n/a	n/a	-	-	No bias	No bias
	Sex	-	-	n/a	n/a	-	-	No bias	No bias
	Recovery								
	Temporal	-	-	n/a	n/a	-	-	Bias	Bias
	Spatial	-	-	n/a	n/a	-	-	?	?
	Sex	-	-	n/a	n/a	-	-	Bias	Bias
	Size	-	-	n/a	n/a	-	-	No bias	No bias
Adams	*Application*								
	Temporal	Bias	No bias	-	-	-	-	Bias	Bias
	Spatial	No bias	Bias	-	-	-	-	Bias	Bias
	Sex	No bias	No bias	-	-	-	-	No bias	No bias
	Recovery								
	Temporal	No bias	Bias	-	-	-	-	No bias	Bias
	Spatial	Bias	Bias	-	-	-	-	Bias	Bias
	Sex	No bias	No bias	-	-	-	-	No bias	No bias
	Size	No bias	No bias	-	-	-	-	No bias	No bias
Eagle	*Application*								
	Temporal	-	-	-	-	-	-	No bias	No bias
	Spatial	-	-	-	-	-	-	No bias	No bias
	Sex	-	-	-	-	-	-	No bias	No bias
	Recovery								
	Temporal	-	-	-	-	-	-	No bias	No bias
	Spatial	-	-	-	-	-	-	No bias	No bias
	Sex	-	-	-	-	-	-	No bias	No bias
	Size	-	-	-	-	-	-	No bias	No bias
Seymour	*Application*								
	Temporal	No bias	No bias	-	-	-	-	No bias	No bias
	Spatial	Bias	Bias	-	-	-	-	No bias	No bias
	Sex	Bias	No bias	-	-	-	-	No bias	No bias
	Recovery								
	Temporal	Bias	Bias	-	-	-	-	Bias	No bias
	Spatial	Bias	No bias	-	-	-	-	?	?
	Sex	No bias	No bias	-	-	-	-	No bias	No bias
	Size	No bias	No bias	-	-	-	-	No bias	No bias

Continued

Appendix 1. Results of statistical tests for sampling bias in Fraser River sockeye mark-recapture studies, 1995-1998. *Bias* indicates a significant chi-square test result ($p < 0.05$), except Kolmogorov-Smirnov 2-sample test used for size.

		1995		1996		1997		1998	
Study	Test type	Male	Female	Male	Female	Male	Female	Male	Female
Chilko	*Application*								
	Temporal	Bias	Bias	n/a	n/a	n/a	n/a	No bias	Bias
	Spatial	No bias	No bias	n/a	n/a	n/a	n/a	No bias	No bias
	Sex	Bias	Bias	n/a	n/a	n/a	n/a	No bias	No bias
	Recovery								
	Temporal	No bias	Bias	n/a	n/a	n/a	n/a	Bias	Bias
	Spatial	?	?	n/a	n/a	n/a	n/a	?	?
	Sex	No bias	No bias	n/a	n/a	n/a	n/a	Bias	No bias
	Size	Bias	Bias	n/a	n/a	n/a	n/a	No bias	No bias
Horsefly	*Application*								
	Temporal	Bias	Bias	-	-	Bias	Bias	No bias	Bias
	Spatial	Bias	No bias	-	-	No bias	Bias	Bias	Bias
	Sex	No bias	No bias	-	-	No bias	No bias	Bias	Bias
	Recovery								
	Temporal	No bias	Bias	-	-	Bias	Bias	Bias	No bias
	Spatial	?	?	-	-	?	?	?	?
	Sex	No bias	No bias	-	-	Bias	Bias	No bias	No bias
	Size	No bias	No bias	-	-	Bias	No bias	No bias	No bias
Mitchell	*Application*								
	Temporal	-	-	-	-	Bias	Bias	Bias	Bias
	Spatial	-	-	-	-	Bias	No bias	Bias	No bias
	Sex	-	-	-	-	Bias	Bias	No bias	No bias
	Recovery								
	Temporal	-	-	-	-	No bias	No bias	No bias	No bias
	Spatial	-	-	-	-	No bias	No bias	?	?
	Sex	-	-	-	-	No bias	No bias	No bias	No bias
	Size	-	-	-	-	No bias	No bias	No bias	No bias
Middle	*Application*								
	Temporal	-	-	-	-	n/a	n/a	No bias	Bias
	Spatial	-	-	-	-	n/a	n/a	Bias	Bias
	Sex	-	-	-	-	n/a	n/a	No bias	No bias
	Recovery								
	Temporal	-	-	-	-	n/a	n/a	No bias	No bias
	Spatial	-	-	-	-	n/a	n/a	No bias	No bias
	Sex	-	-	-	-	n/a	n/a	No bias	No bias
	Size	-	-	-	-	n/a	n/a	No bias	No bias
Tachie	*Application*								
	Temporal	-	-	-	-	No bias	No bias	No bias	No bias
	Spatial	-	-	-	-	Bias	No bias	No bias	No bias
	Sex	-	-	-	-	Bias	Bias	No bias	No bias
	Recovery								
	Temporal	-	-	-	-	Bias	Bias	No bias	No bias
	Spatial	-	-	-	-	Bias	No bias	No bias	No bias
	Sex	-	-	-	-	Bias	Bias	No bias	No bias
	Size	-	-	-	-	No bias	No bias	No bias	No bias

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Adams study area: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	1,031	1	0.1%	63	6.1%	233	12.5	0.3			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	4,189	10	0.2%	190	4.5%	623	12.3	0.2			
Standard	1994	4,784	1	0.0%	407	8.5%	964	12.8	0.4			
	1995	1,097	1	0.1%	62	5.7%	210	12.9	0.3			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	4,784	1	0.0%	407	8.5%	964	12.8	0.4	2	0.2%	99.5%
	1995	2,128	2	0.1%	125	5.9%	443	12.7	0.3	14	3.2%	93.7%
	1996	0	0	-	0	-	0	-	-	0	-	91.5%
	1997	0	0	-	0	-	0	-	-	0	-	94.7%
	1998	4,189	10	0.2%	190	4.5%	623	12.3	0.2	5	0.8%	97.7%
Adams study area: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	1,201	1	0.1%	101	8.4%	230	13.2	0.3			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	4,941	13	0.3%	242	4.9%	787	13.3	0.2			
Standard	1994	5,430	6	0.1%	656	12.1%	1,099	14.7	0.4			
	1995	1,132	1	0.1%	79	7.0%	242	16.1	2.3			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	5,430	6	0.1%	656	12.1%	1,099	14.7	0.4	6	0.5%	-
	1995	2,333	2	0.1%	180	7.7%	472	14.7	1.6	23	4.9%	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	4,941	13	0.3%	242	4.9%	787	13.3	0.2	14	1.8%	-
Adams study area: males and females combined												
Pooled	1994	10,214	7	0.1%	1,063	10.4%	2,063	13.8	0.4	8	0.4%	99.5%
	1995	4,461	4	0.1%	305	6.8%	915	13.7	1.2	37	4.0%	93.7%
	1996	0	0	-	0	-	0	-	-	0	-	91.5%
	1997	0	0	-	0	-	0	-	-	0	-	94.7%
	1998	9,130	23	0.3%	432	4.7%	1,410	12.8	0.2	19	1.3%	97.7%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Birkenhead River: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	458	0	0.0%	37	8.1%	179	15.3	0.4			
	1996	901	2	0.2%	147	16.3%	294	19.3	0.3			
	1997	0	0	-	0	-	0	-	-			
	1998	1,609	4	0.2%	49	3.0%	412	21.1	0.3			
Standard	1994	1,060	14	1.3%	98	9.2%	270	17.1	0.3			
	1995	453	0	0.0%	40	8.8%	182	15.1	0.4			
	1996	845	0	0.0%	171	20.2%	270	19.5	0.4			
	1997	1,252	9	0.7%	229	18.3%	180	21.1	0.5			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	1,060	14	1.3%	98	9.2%	270	17.1	0.3	0	0.0%	99.8%
	1995	911	0	0.0%	77	8.5%	361	15.2	0.4	4	1.1%	92.0%
	1996	1,746	2	0.1%	318	18.2%	564	19.4	0.3	3	0.5%	91.9%
	1997	1,252	9	0.7%	229	18.3%	180	21.1	0.5	2	1.1%	94.8%
	1998	1,609	4	0.2%	49	3.0%	412	21.1	0.3	1	0.2%	95.4%
Birkenhead River: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	351	0	0.0%	32	9.1%	96	17.2	0.7			
	1996	746	1	0.1%	131	17.6%	217	18.8	0.4			
	1997	0	0	-	0	-	0	-	-			
	1998	1,232	3	0.2%	51	4.1%	383	22.1	0.3			
Standard	1994	729	16	2.2%	72	9.9%	150	18.1	0.4			
	1995	382	0	0.0%	44	11.5%	121	16.8	0.5			
	1996	841	2	0.2%	165	19.6%	219	19.0	0.3			
	1997	1,466	23	1.6%	289	19.7%	227	22.1	0.4			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	729	16	2.2%	72	9.9%	150	18.1	0.4	0	0.0%	-
	1995	733	0	0.0%	76	10.4%	217	17.0	0.6	7	3.2%	-
	1996	1,587	3	0.2%	296	18.7%	436	18.9	0.4	3	0.7%	-
	1997	1,466	23	1.6%	289	19.7%	227	22.1	0.4	3	1.3%	-
	1998	1,232	3	0.2%	51	4.1%	383	22.1	0.3	0	0.0%	-
Birkenhead River: males and females combined												
Pooled	1994	1,789	30	1.7%	170	9.5%	420	17.5	0.3	0	0.0%	99.8%
	1995	1,644	0	0.0%	153	9.3%	578	15.9	0.5	11	1.9%	92.0%
	1996	3,333	5	0.2%	614	18.4%	1,000	19.2	0.4	6	0.6%	91.9%
	1997	2,718	32	1.2%	518	19.1%	407	21.7	0.5	5	1.2%	94.8%
	1998	2,841	7	0.2%	100	3.5%	795	21.5	0.3	1	0.1%	95.4%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Chilko System: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	1,319	0	0.0%	0	0.0%	383	31.8	0.4			
	1996	3,053	1	0.0%	15	0.5%	712	32.1	0.3			
	1997	2,955	13	0.4%	3	0.1%	453	27.5	0.4			
	1998	3,765	45	1.2%	9	0.2%	843	31.7	0.3			
Standard	1994	2,075	9	0.4%	4	0.2%	473	28.8	0.3			
	1995	1,380	2	0.1%	0	0.0%	419	31.6	0.3			
	1996	3,064	5	0.2%	22	0.7%	638	32.6	0.3			
	1997	3,309	25	0.8%	27	0.8%	528	27.2	0.4			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	2,075	9	0.4%	4	0.2%	473	28.8	0.3	3	0.6%	97.1%
	1995	2,699	2	0.1%	0	0.0%	802	31.7	0.3	0	0.0%	93.5%
	1996	6,117	6	0.1%	37	0.6%	1,350	32.3	0.3	1	0.1%	94.8%
	1997	6,264	38	0.6%	30	0.5%	981	27.3	0.4	4	0.4%	91.5%
	1998	3,765	45	1.2%	9	0.2%	843	31.7	0.3	3	0.4%	92.2%
Chilko System: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	869	0	0.0%	0	0.0%	294	31.1	0.4			
	1996	2,581	0	0.0%	16	0.6%	647	31.9	0.3			
	1997	2,401	6	0.2%	11	0.5%	329	27.0	0.5			
	1998	3,109	23	0.7%	12	0.4%	724	31.5	0.3			
Standard	1994	1,512	5	0.3%	0	0.0%	286	28.2	0.4			
	1995	817	3	0.4%	0	0.0%	279	31.7	0.4			
	1996	2,627	0	0.0%	15	0.6%	677	31.8	0.3			
	1997	2,364	9	0.4%	8	0.3%	357	27.4	0.5			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	1,512	5	0.3%	0	0.0%	286	28.2	0.4	0	0.0%	-
	1995	1,686	3	0.2%	0	0.0%	573	31.4	0.4	1	0.2%	-
	1996	5,208	0	0.0%	31	0.6%	1,324	31.9	0.3	0	0.0%	-
	1997	4,765	15	0.3%	19	0.4%	686	27.2	0.5	0	0.0%	-
	1998	3,109	23	0.7%	12	0.4%	724	31.5	0.3	2	0.3%	-
Chilko System: males and females combined												
Pooled	1994	3,587	14	0.4%	4	0.1%	759	28.6	0.3	3	0.4%	97.1%
	1995	4,385	5	0.1%	0	0.0%	1,375	31.6	0.4	1	0.1%	93.5%
	1996	11,325	6	0.1%	68	0.6%	2,674	32.1	0.3	1	0.0%	94.8%
	1997	11,029	53	0.5%	49	0.4%	1,667	27.3	0.5	4	0.2%	91.5%
	1998	6,874	68	1.0%	21	0.3%	1,567	31.6	0.3	5	0.3%	92.2%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Early Stuart creeks: females												
Fence	1994	0	0	-	-	-	0	-	0.0	0.0	-	91.6%
	1995	0	0	-	-	-	0	-	0.0	0	-	88.7%
	1996	138	0	0.0%	-	-	51	11.1	0.4	1	2.0%	96.5%
	1997	112	4	3.6%	-	-	67	5.8	0.6	30	44.8%	76.0%
	1998	14	0	0.0%	-	-	9	6.8	0.4	1	11.1%	52.0%
Early Stuart creeks: males												
Fence	1994	0	0	-	-	-	0	-	-	0	-	
	1995	0	0	-	-	-	0	-	-	0	-	
	1996	147	1	0.7%	-	-	61	11.7	0.4	1	1.6%	
	1997	222	14	6.3%	-	-	129	5.8	0.6	34	26.4%	
	1998	23	4	17.4%	-	-	10	10.4	0.2	2	20.0%	
Early Stuart creeks: males and females combined												
Fence	1994	0	0	-	-	-	0	-	-	0	-	91.6%
	1995	0	0	-	-	-	0	-	-	0	-	88.7%
	1996	285	1	0.4%	-	-	112	11.4	0.4	2	1.8%	96.5%
	1997	334	18	5.4%	-	-	196	5.8	0.6	64	32.7%	76.0%
	1998	37	4	10.8%	-	-	19	8.7	0.3	3	15.8%	52.0%
Eagle River: females												
	1998	-	-	-	-	-	-	-	-	-	-	-
Eagle River: males												
	1998	-	-	-	-	-	-	-	-	-	-	-
Eagle River: males and females combined												
Low stress	1994											87.5%
	1995											100.0%
	1996											96.3%
	1997											90.1%
	1998	-	-	-	-	-	-	-	-	-	-	97.3%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Horsefly System: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	417	0	0.0%	16	3.8%	90	16.4	0.5			
	1996	0	0	-	0	-	0	-	-			
	1997	3,102	0	0.0%	216	7.0%	256	15.8	0.4			
	1998	4,858	46	0.9%	395	8.1%	645	16.0	0.3			
Standard	1994	2,914	52	1.8%	106	3.6%	428	17.6	0.3			
	1995	424	7	1.7%	23	5.4%	79	15.7	0.5			
	1996	0	0	-	0	-	0	-	-			
	1997	3,223	11	0.3%	234	7.3%	244	15.3	0.3			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	2,914	52	1.8%	106	3.6%	428	17.6	0.3	2	0.5%	99.0%
	1995	841	7	0.8%	39	4.6%	169	16.0	0.5	0	0.0%	97.3%
	1996	0	0	-	0	-	0	-	-	0	-	94.7%
	1997	6,325	11	0.2%	450	7.1%	500	15.6	0.4	1	0.2%	93.3%
	1998	4,858	46	0.9%	395	8.1%	645	16.0	0.3	4	0.6%	89.1%
Horsefly System: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	325	1	0.3%	12	3.7%	58	15.9	0.7			
	1996	0	0	-	0	-	0	-	-			
	1997	2,607	1	0.0%	204	7.8%	244	16.1	0.4			
	1998	5,307	64	1.2%	471	8.9%	788	16.0	0.2			
Standard	1994	2,431	54	2.2%	84	3.5%	356	17.4	0.3			
	1995	317	8	2.5%	18	5.7%	46	15.6	0.7			
	1996	0	0	-	0	-	0	-	-			
	1997	2,644	9	0.3%	169	6.4%	201	15.7	0.4			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	2,431	54	2.2%	84	3.5%	356	17.4	0.3	0	0.0%	-
	1995	642	9	1.4%	30	4.7%	104	15.7	0.7	0	0.0%	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	5,251	10	0.2%	373	7.1%	445	15.9	0.4	1	0.2%	-
	1998	5,307	64	1.2%	471	8.9%	788	16.0	0.2	4	0.5%	-
Horsefly System: males and females combined												
Pooled	1994	5,345	106	2.0%	190	3.6%	784	17.5	0.3	2	0.3%	99.0%
	1995	1,483	16	1.1%	69	4.7%	273	15.9	0.6	0	0.0%	97.3%
	1996	0	0	-	0	-	0	-	-	0	-	94.7%
	1997	11,576	21	0.2%	823	7.1%	945	15.7	0.4	2	0.2%	93.3%
	1998	10,165	110	1.1%	866	8.5%	1,433	16.0	0.2	8	0.6%	89.1%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Middle River: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,110	5	0.5%	18	1.6%	211	17.9	0.4			
	1998	364	41	11.3%	29	8.0%	364	17.5	0.2			
Standard	1994	116	10	8.6%	32	27.6%	16	13.4	0.9			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,457	13	0.9%	19	1.3%	254	17.1	0.3			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	116	10	8.6%	32	27.6%	16	13.4	0.9	0	0.0%	99.5%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	86.4%
	1997	2,567	18	0.7%	37	1.4%	465	17.5	0.4	1	0.2%	95.5%
	1998	364	41	11.3%	29	8.0%	364	17.5	0.2	0	0.0%	98.6%
Middle River: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	787	2	0.3%	28	3.6%	136	21.0	0.6			
	1998	354	6	1.7%	45	12.7%	354	17.7	0.3			
Standard	1994	113	11	9.7%	47	41.6%	20	15.3	1.2			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	838	3	0.4%	15	1.8%	176	19.6	0.5			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	113	11	9.7%	47	41.6%	20	15.3	1.2	0	0.0%	-
	1995	0	0	-	0	-	0	-	-	-	-	-
	1996	0	0	-	0	-	0	-	-	-	-	-
	1997	1,625	5	0.3%	43	2.6%	312	20.2	0.6	1	0.3%	-
	1998	354	6	1.7%	45	12.7%	354	17.7	0.3	0	0.0%	-
Middle River: males and females combined												
Pooled	1994	229	21	9.2%	79	34.5%	36	14.4	1.0	0	0.0%	99.5%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	86.4%
	1997	4,192	23	0.5%	80	1.9%	777	18.6	0.5	2	0.3%	95.5%
	1998	718	47	6.5%	74	10.3%	718	17.6	0.3	0	0.0%	98.6%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Mitchell River: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	851	2	0.2%	52	6.1%	82	13.3	0.8			
	1998	1,707	1	0.1%	26	1.5%	201	15.1	0.4			
Standard	1994	539	1	0.2%	4	0.7%	74	14.8	0.7			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	846	13	1.5%	58	6.9%	91	13.1	0.5			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	539	1	0.2%	4	0.7%	74	14.8	0.7	2	2.7%	99.7%
	1995	0	0	-	0	-	0	-	-	0	-	97.4%
	1996	0	0	-	0	-	0	-	-	0	-	100.0%
	1997	1,697	15	0.9%	110	6.5%	173	13.2	0.7	3	1.7%	92.7%
	1998	1,707	1	0.1%	26	1.5%	201	15.1	0.4	1	0.5%	94.6%
Mitchell River: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,175	5	0.4%	133	11.3%	110	13.0	0.5			
	1998	1,724	4	0.2%	59	3.4%	218	14.3	0.4			
Standard	1994	459	0	0.0%	3	0.7%	46	14.4	0.7			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,186	20	1.7%	102	8.6%	126	14.3	0.5			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	459	0	0.0%	3	0.7%	46	14.4	0.7	0	0.0%	-
	1995	0	0	-	0	-	0	-	-	0	-	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	2,361	25	1.1%	235	10.0%	236	13.7	0.5	2	0.8%	-
	1998	1,724	4	0.2%	59	3.4%	218	14.3	0.4	2	0.9%	-
Mitchell River: males and females combined												
Pooled	1994	998	1	0.1%	7	0.7%	120	14.7	0.7	2	1.7%	99.7%
	1995	0	0	-	0	-	0	-	-	0	-	97.4%
	1996	0	0	-	0	-	0	-	-	0	-	100.0%
	1997	4,058	40	1.0%	345	8.5%	409	13.5	0.6	5	1.2%	92.7%
	1998	3,431	5	0.1%	85	2.5%	419	14.7	0.4	3	0.7%	94.6%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Pitt River, upper: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	222	0	0.0%	0	0.0%	96	14.0	0.3			
	1997	451	14	3.1%	19	4.2%	60	17.1	0.6			
	1998	559	0	0.0%	45	8.1%	46	39.7	0.7			
Standard	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	0	0	-	0	-	0	-	-	0	-	98.3%
	1995	0	0	-	0	-	0	-	-	0	-	90.0%
	1996	222	0	0.0%	0	0.0%	96	14.0	0.3	0	0.0%	95.7%
	1997	451	14	3.1%	19	4.2%	60	17.1	0.6	1	1.7%	91.2%
	1998	559	0	0.0%	45	8.1%	46	39.7	0.7	0	0.0%	96.9%
Pitt River, upper: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	223	3	1.3%	4	1.8%	62	13.9	0.4			
	1997	490	13	2.7%	29	5.9%	46	20.7	0.4			
	1998	368	1	0.3%	25	6.8%	36	34.7	0.8			
Standard	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	0	0	-	0	-	0	-	-	0	-	-
	1995	0	0	-	0	-	0	-	-	0	-	-
	1996	223	3	1.3%	4	1.8%	62	13.9	0.4	1	1.6%	-
	1997	490	13	2.7%	29	5.9%	46	20.7	0.4	0	0.0%	-
	1998	368	1	0.3%	25	6.8%	36	34.7	0.8	0	0.0%	-
Pitt River, upper: males and females combined												
Pooled	1994	0	0	-	0	-	0	-	-	0	-	98.3%
	1995	0	0	-	0	-	0	-	-	0	-	90.0%
	1996	445	3	0.7%	4	0.9%	158	14.0	0.3	1	0.6%	95.7%
	1997	941	27	2.9%	48	5.1%	106	18.7	0.5	1	0.9%	91.2%
	1998	927	1	0.1%	70	7.6%	82	37.5	0.7	0	0.0%	96.9%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Seymour River: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	221	0	0.0%	18	8.1%	41	13.9	0.5			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	430	4	0.9%	75	17.4%	72	12.7	0.6			
Standard	1994	359	2	0.6%	15	4.2%	62	11.3	0.5			
	1995	167	0	0.0%	9	5.4%	32	12.6	0.6			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	359	2	0.6%	15	4.2%	62	11.3	0.5	2	3.2%	98.9%
	1995	388	0	0.0%	27	7.0%	73	13.3	0.6	1	1.4%	98.3%
	1996	0	0	-	0	-	0	-	-	0	-	95.0%
	1997	0	0	-	0	-	0	-	-	0	-	84.6%
	1998	430	4	0.9%	75	17.4%	72	12.7	0.6	2	2.8%	96.7%
Seymour River: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	247	1	0.4%	16	6.5%	54	12.1	0.4			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	466	4	0.9%	103	22.1%	54	12.3	0.6			
Standard	1994	624	5	0.8%	35	5.6%	54	12.1	0.5			
	1995	304	0	0.0%	24	7.9%	54	13.2	0.5			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	624	5	0.8%	35	5.6%	54	12.1	0.5	0	0.0%	-
	1995	551	1	0.2%	40	7.3%	108	12.7	0.5	1	0.9%	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	466	4	0.9%	103	22.1%	54	12.3	0.6	2	3.7%	-
Seymour River: males and females combined												
Pooled	1994	983	7	0.7%	50	5.1%	116	11.7	0.5	2	1.7%	98.9%
	1995	939	1	0.1%	67	7.1%	181	12.9	0.5	2	1.1%	98.3%
	1996	0	0	-	0	-	0	-	-	0	-	95.0%
	1997	0	0	-	0	-	0	-	-	0	-	84.6%
	1998	896	8	0.9%	178	19.9%	126	12.5	0.6	4	3.2%	96.7%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Shuswap System: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	1,415	1	0.1%	40	2.8%	283	15.0	0.3			
Standard	1994	1,919	5	0.3%	3	0.2%	502	14.2	0.2			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	1,919	5	0.3%	3	0.2%	502	14.2	0.2	0	0.0%	99.1%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	89.3%
	1997	0	0	-	0	-	0	-	-	0	-	66.7%
	1998	1,415	1	0.1%	40	2.8%	283	15.0	0.3	2	0.7%	96.3%
Shuswap System: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	1,620	6	0.4%	45	2.8%	353	16.5	0.3			
Standard	1994	2,167	19	0.9%	11	0.5%	720	16.8	0.2			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	2,167	19	0.9%	11	0.5%	720	16.8	0.2	1	0.1%	-
	1995	0	0	-	0	-	0	-	-	0	-	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	1,620	6	0.4%	45	2.8%	353	16.5	0.3	5	1.4%	-
Shuswap System: males and females combined												
Pooled	1994	4,086	24	0.6%	14	0.3%	1,222	15.7	0.2	1	0.1%	99.1%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	89.3%
	1997	0	0	-	0	-	0	-	-	0	-	66.7%
	1998	3,035	7	0.2%	85	2.8%	636	15.8	0.3	7	1.1%	96.3%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Stellako River: females												
Fence	1994	990	78	7.9%	0	0.0%	289	21.6	0.3	1	0.3%	89.1%
and	1995	497	24	4.8%	0	0.0%	147	15.2	0.3	9	6.1%	74.9%
Standard	1996	1,930	25	1.3%	0	0.0%	625	25.5	0.2	0	0.0%	93.4%
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	1,105	4	0.4%	0	0.0%	392	22.2	0.3	0	0.0%	98.4%
Stellako River: males												
Fence	1994	409	36	8.8%	0	0.0%	90	21.5	0.6	0	0.0%	-
and	1995	714	22	3.1%	0	0.0%	297	19.5	0.2	5	1.7%	-
Standard	1996	1,341	31	2.3%	0	0.0%	410	27.1	0.2	0	0.0%	-
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	750	4	0.5%	0	0.0%	276	22.3	0.3	0	0.0%	-
Stellako River: males and females combined												
Fence	1994	1,399	114	8.1%	0	0.0%	379	21.6	0.4	1	0.3%	89.1%
and	1995	1,211	46	3.8%	0	0.0%	444	18.1	0.3	14	3.2%	74.9%
Standard	1996	3,271	56	1.7%	0	0.0%	1,035	26.1	0.2	0	0.0%	93.4%
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	1,855	8	0.4%	0	0.0%	668	22.2	0.3	0	0.0%	98.4%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Tachie River: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	2,388	10	0.4%	93	3.9%	505	15.2	0.3			
	1998	408	5	1.2%	35	8.6%	64	14.5	0.6			
Standard	1994	950	22	2.3%	82	8.6%	175	16.4	0.4			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	2,318	11	0.5%	86	3.7%	447	14.8	0.3			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	950	22	2.3%	82	8.6%	175	16.4	0.4	3	1.7%	97.0%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	84.7%
	1997	4,706	21	0.4%	179	3.8%	952	15.0	0.3	25	2.6%	87.5%
	1998	408	5	1.2%	35	8.6%	64	14.8	0.6	1	1.6%	98.4%
Tachie River: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,645	10	0.6%	101	6.1%	292	18.4	0.4			
	1998	326	4	1.2%	22	6.7%	41	16.3	0.8			
Standard	1994	849	28	3.3%	120	14.1%	168	17.5	0.4			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	1,508	9	0.6%	94	6.2%	275	18.8	0.4			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	849	28	3.3%	120	14.1%	168	17.5	0.4	2	1.2%	-
	1995	0	0	-	0	-	0	-	-	0	-	-
	1996	0	0	-	0	-	0	-	-	0	-	-
	1997	3,153	19	0.6%	195	6.2%	567	18.6	0.4	3	0.5%	-
	1998	326	4	1.2%	22	6.7%	41	16.3	0.8	1	2.4%	-
Tachie River: males and females combined												
Pooled	1994	1,799	50	2.8%	202	11.2%	343	17.0	0.4	5	1.5%	97.0%
	1995	0	0	-	0	-	0	-	-	0	-	100.0%
	1996	0	0	-	0	-	0	-	-	0	-	84.7%
	1997	7,859	40	0.5%	374	4.8%	1,519	16.4	0.3	28	1.8%	87.5%
	1998	734	9	1.2%	57	7.8%	105	15.4	0.7	2	1.9%	98.4%

Continued

Appendix 2. Indicators of the condition of sockeye salmon spawning in mark recapture study areas, from 1994 to 1998, continued.

Tagging method	Year	No. tagged	Requiring ventilation		Recaptured 1 or more times		No. rec'd	'Days out'		<5 'days out'		Mean spawning success (%)
			No.	%	No.	%		Mean	S.E.	No.	%	
Weaver Creek: females												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	684	2	0.3%	8	1.2%	259	7.3	0.2			
	1997	0	0	-	0	-	0	-	-			
	1998	203	14	6.9%	4	2.0%	91	5.4	0.3			
Standard	1994	0	0	-	0	-	21	7.6	0.0			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	0	0	-	0	-	21	7.6	0.0	11	52.4%	97.9%
	1995	0	0	-	0	-	0	-	-	0	-	56.0%
	1996	684	2	0.3%	8	1.2%	259	7.3	0.2	77	29.7%	48.7%
	1997	0	0	-	0	-	0	-	-	0	-	50.7%
	1998	203	14	6.9%	4	2.0%	91	5.4	0.3	44	48.4%	90.4%
Weaver Creek: males												
Low stress	1994	0	0	-	0	-	0	-	-			
	1995	0	0	-	0	-	0	-	-			
	1996	934	4	0.4%	19	2.0%	469	9.0	0.0			
	1997	0	0	-	0	-	0	-	-			
	1998	191	12	6.3%	2	1.0%	108	6.5	0.0			
Standard	1994	0	0	-	0	-	29	10.2	0.0			
	1995	0	0	-	0	-	0	-	-			
	1996	0	0	-	0	-	0	-	-			
	1997	0	0	-	0	-	0	-	-			
	1998	0	0	-	0	-	0	-	-			
Pooled	1994	0	0	-	0	-	29	10.2	0.0	6	20.7%	-
	1995	0	0	-	0	-	0	-	-	0	-	-
	1996	934	4	0.4%	19	2.0%	469	9.0	0.0	100	21.3%	-
	1997	0	0	-	0	-	0	-	-	0	-	-
	1998	191	12	6.3%	2	1.0%	108	6.5	0.0	44	40.7%	-
Weaver Creek: males and females combined												
Pooled	1994	0	0	-	0	-	50	9.1	0.0	17	34.0%	97.9%
	1995	0	0	-	0	-	0	-	-	0	-	56.0%
	1996	1,618	6	0.4%	27	1.7%	728	8.4	0.1	177	24.3%	48.7%
	1997	0	0	-	0	-	0	-	-	0	-	50.7%
	1998	394	26	6.6%	6	1.5%	199	6.0	0.2	88	44.2%	90.4%

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Adams study area: females									
1994	20.2%	0.0%	-20.2%	*20.4%*	*17.4%*	*- 3.0%*	*97.3%*	*99.3%*	*2.0%*
1995	20.8%	0.0%	-20.8%	*20.4%*	*28.0%*	*7.6%*	*92.3%*	*75.9%*	*-16.4%*
1996	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-
1998	*14.8%*	*30.0%*	*15.2%*	*14.8%*	*15.8%*	*1.0%*	*94.0%*	*95.4%*	*1.4%*
Adams study area: males									
1994	20.2%	16.7%	- 3.6%	*20.6%*	*17.5%*	*- 3.1%*			
1995	20.2%	0.0%	-20.2%	*19.4%*	*30.6%*	*11.2%*			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	*15.9%*	*23.1%*	*7.2%*	*16.1%*	*12.0%*	*- 4.1%*			
Adams study area: pooled									
1994	20.2%	14.3%	- 5.9%	*20.5%*	*17.5%*	*- 3.0%*			
1995	20.5%	0.0%	-20.5%	*19.9%*	*29.5%*	*9.7%*			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	*15.4%*	*26.1%*	*10.7%*	*15.5%*	*13.7%*	*- 1.9%*			
Birkenhead River: females									
1994	*25.4%*	*35.7%*	*10.4%*	*24.6%*	*33.7%*	*9.0%*	*100.0%*	*99.8%*	*- 0.2%*
1995	39.5%	-	-	*39.3%*	*42.9%*	*3.5%*	*92.5%*	*90.2%*	*- 2.3%*
1996	*32.2%*	*50.0%*	*17.8%*	*32.7%*	*30.5%*	*- 2.2%*	*88.3%*	*91.7%*	*3.4%*
1997	*14.4%*	*11.1%*	*- 3.3%*	*13.9%*	*16.6%*	*2.7%*	*92.4%*	*94.5%*	*2.0%*
1998	*25.5%*	*25.0%*	*- 0.5%*	*25.5%*	*28.6%*	*3.1%*	*91.9%*	*95.3%*	*3.5%*
Birkenhead River: males									
1994	20.2%	*31.3%*	*11.1%*	20.2%	*23.6%*	*3.4%*			
1995	29.6%	-	-	29.2%	*32.9%*	*3.7%*			
1996	27.5%	*33.3%*	*5.9%*	28.0%	*25.0%*	*- 3.0%*			
1997	*15.6%*	*8.7%*	*- 6.9%*	*16.4%*	*11.8%*	*- 4.6%*			
1998	*30.7%*	*33.3%*	*2.6%*	*31.5%*	*21.6%*	*- 9.9%*			
Birkenhead River: pooled									
1994	23.2%	*33.3%*	*10.1%*	22.9%	*29.4%*	*6.6%*			
1995	35.1%	-	-	*34.9%*	*37.9%*	*3.0%*			
1996	*29.9%*	*40.0%*	*10.1%*	*30.5%*	*27.9%*	*- 2.6%*			
1997	*15.0%*	*9.4%*	*- 5.7%*	*15.2%*	*13.9%*	*- 1.3%*			
1998	*27.7%*	*28.6%*	*0.8%*	*28.1%*	*25.0%*	*- 3.1%*			

Continued

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Chilko System: females									
1994	22.7%	33.3%	10.7%	22.1%	50.0%	27.9%	92.7%	95.8%	3.1%
1995	29.7%	50.0%	20.3%	29.7%	-	-	94.9%	93.1%	- 1.8%
1996	22.1%	0.0%	-22.1%	22.0%	29.7%	7.7%	93.6%	87.7%	- 5.9%
1997	15.6%	18.4%	2.8%	15.7%	6.7%	- 9.0%	93.7%	83.0%	-10.7%
1998	22.5%	11.1%	-11.4%	22.4%	0.0%	-22.4%	94.9%	85.7%	- 9.2%
Chilko System: males									
1994	18.9%	0.0%	-18.9%	18.4%	-	-			
1995	33.9%	66.7%	32.7%	34.0%	-	-			
1996	25.4%	-	-	25.4%	25.8%	0.4%			
1997	14.4%	6.7%	- 7.8%	14.4%	10.5%	- 3.9%			
1998	23.3%	26.1%	2.8%	23.3%	8.3%	-15.0%			
Chilko System: pooled									
1994	21.1%	21.4%	0.3%	20.5%	50.0%	29.5%			
1995	31.3%	60.0%	28.7%	31.4%	-	-			
1996	23.6%	0.0%	-23.6%	23.6%	27.9%	4.4%			
1997	15.1%	15.1%	0.0%	15.1%	8.2%	- 7.0%			
1998	22.9%	16.2%	- 6.7%	22.9%	4.8%	-18.1%			
Eagle River: females									
1994	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-
1998	12.3%	100.0%	87.7%	13.5%	-	-	90.0%	96.9%	6.9%
Eagle River: males									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	13.0%	25.0%	12.0%	13.4%	16.7%	3.2%			
Eagle River: pooled									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	12.7%	40.0%	27.3%	13.5%	16.7%	3.2%			

Continued

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Early Stuart creeks: females									
1994	-	-	-	-	-	-	-	92.6%	-
1995	-	-	-	-	-	-	-	87.7%	-
1996	37.0%	-	-	-	-	-	*95.9%*	*95.6%*	*- 0.4%*
1997	59.3%	75.0%	15.7%	-	-	-	*53.0%*	*71.3%*	*18.3%*
1998	64.3%	-	-	-	-	-	22.2%	50.0%	27.8%
Early Stuart creeks: males									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	41.1%	100.0%	58.9%	-	-	-			
1997	*58.2%*	*57.1%*	*- 1.0%*	-	-	-			
1998	*42.1%*	*50.0%*	7.9%	-	-	-			
Early Stuart creeks: pooled									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	39.1%	100.0%	60.9%	-	-	-			
1997	*58.5%*	*61.1%*	2.6%	-	-	-			
1998	51.5%	50.0%	- 1.5%	-	-	-			
Horsefly System: females									
1994	*14.7%*	*11.5%*	*- 3.2%*	*15.2%*	*12.3%*	*- 3.0%*	*92.0%*	*98.9%*	*6.9%*
1995	19.8%	57.1%	37.3%	*20.6%*	*12.8%*	*- 7.8%*	*98.8%*	*97.3%*	*- 1.5%*
1996	-	-	-	-	-	-	-	-	-
1997	*9.4%*	*0.0%*	*- 9.4%*	*9.4%*	*8.4%*	*- 1.0%*	*83.6%*	*88.6%*	*5.0%*
1998	*10.2%*	8.7%	*- 1.5%*	*10.2%*	*10.9%*	*0.7%*	*80.1%*	*83.6%*	*3.5%*
Horsefly System: males									
1994	*10.9%*	*11.1%*	*0.2%*	*15.3%*	*15.5%*	*0.1%*			
1995	16.4%	0.0%	-16.4%	*16.5%*	6.7%	*- 9.8%*			
1996	-	-	-	-	-	-			
1997	*10.0%*	*0.0%*	*-10.0%*	*9.9%*	*10.7%*	*0.8%*			
1998	*10.9%*	*12.5%*	*1.6%*	*11.0%*	*10.2%*	*- 0.8%*			
Horsefly System: pooled									
1994	*13.0%*	*11.3%*	*- 1.7%*	*15.3%*	*13.7%*	*- 1.6%*			
1995	*18.3%*	*25.0%*	*6.7%*	*18.8%*	*10.1%*	*- 8.7%*			
1996	-	-	-	-	-	-			
1997	*9.7%*	*0.0%*	*- 9.7%*	*9.7%*	*9.5%*	*- 0.2%*			
1998	*10.6%*	*10.9%*	*0.3%*	*10.6%*	*10.5%*	*- 0.1%*			

Continued

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Middle River: females									
1994	*13.2%*	*20.0%*	*6.8%*	*66.3%*	*33.7%*	*-32.6%*	100.0%	-	-
1995	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-
1997	*18.8%*	*27.8%*	*9.0%*	*18.8%*	*24.3%*	5.5%	84.0%	94.8%	10.8%
1998	*33.1%*	*2.4%*	*-30.7%*	*29.0%*	*37.9%*	9.0%	97.1%	98.4%	1.3%
Middle River: males									
1994	*16.7%*	*18.2%*	*1.5%*	*64.7%*	*35.3%*	*-29.3%*			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	21.4%	20.0%	- 1.4%	*21.3%*	*25.6%*	*4.3%*			
1998	27.6%	33.3%	5.7%	*25.6%*	*42.2%*	*16.7%*			
Middle River: pooled									
1994	*14.9%*	*19.0%*	*4.1%*	*65.4%*	*34.6%*	*-30.7%*			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	*19.8%*	*26.1%*	*6.3%*	*19.7%*	*25.0%*	*5.3%*			
1998	*30.3%*	*6.4%*	*-23.9%*	*27.3%*	*40.5%*	*13.2%*			
Mitchell River: females									
1994	13.1%	0.0%	-13.1%	13.3%	0.0%	-13.3%	-	-	-
1995	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-
1997	*12.4%*	*0.0%*	*-12.4%*	*12.1%*	*14.5%*	*2.4%*	*85.3%*	*90.8%*	*5.5%*
1998	11.5%	0.0%	-11.5%	*11.7%*	*7.7%*	*- 4.0%*	*94.6%*	*92.1%*	*- 2.5%*
Mitchell River: males									
1994	10.6%	-	-	9.9%	33.3%	23.5%			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	*11.1%*	*4.0%*	*- 7.1%*	*11.6%*	*7.2%*	*- 4.4%*			
1998	12.6%	25.0%	12.4%	*12.7%*	*10.2%*	*- 2.6%*			
Mitchell River: pooled									
1994	12.0%	0.0%	-12.0%	11.7%	14.3%	2.6%			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	*11.6%*	*2.5%*	*- 9.1%*	*11.8%*	*9.6%*	*- 2.3%*			
1998	12.1%	20.0%	7.9%	*12.2%*	*9.4%*	*- 2.8%*			

Continued

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Pitt River, upper: females									
1994	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-
1996	43.2%	-	-	43.2%	-	-	*89.2%*	*94.9%*	*5.6%*
1997	*13.0%*	*21.4%*	*8.4%*	*13.7%*	*5.3%*	*- 8.4%*	*89.3%*	*90.7%*	*1.4%*
1998	8.2%	-	-	*8.4%*	*6.7%*	*- 1.7%*	*87.5%*	*96.3%*	*8.8%*
Pitt River, upper: males									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	27.7%	33.3%	5.6%	27.4%	50.0%	22.6%			
1997	*9.4%*	*7.7%*	*- 1.7%*	*9.5%*	*6.9%*	*- 2.6%*			
1998	9.8%	0.0%	- 9.8%	*9.9%*	*8.0%*	*- 1.9%*			
Pitt River, upper: pooled									
1994	-	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	35.5%	33.3%	- 2.2%	35.4%	50.0%	14.6%			
1997	*11.2%*	*14.8%*	*3.7%*	*11.5%*	*6.3%*	*- 5.3%*			
1998	8.9%	0.0%	- 8.9%	*9.0%*	*7.1%*	*- 1.8%*			
Seymour River: females									
1994	16.7%	0.0%	-16.7%	*16.3%*	*33.3%*	*17.1%*	*98.4%*	*99.3%*	*0.9%*
1995	18.6%	-	-	*19.7%*	*7.4%*	*-12.3%*	*100.0%*	*98.2%*	*- 1.8%*
1996	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-
1998	16.7%	25.0%	8.3%	*16.6%*	*17.3%*	*0.7%*	*94.4%*	*96.3%*	*2.0%*
Seymour River: males									
1994	8.7%	20.0%	11.3%	*8.7%*	*5.7%*	*- 2.9%*			
1995	19.5%	0.0%	-19.5%	*19.2%*	*25.0%*	*5.8%*			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	11.7%	0.0%	-11.7%	*11.0%*	*13.6%*	*2.6%*			
Seymour River: pooled									
1994	11.8%	14.3%	2.5%	*11.5%*	*14.0%*	*2.5%*			
1995	19.1%	0.0%	-19.1%	*19.4%*	*17.9%*	*- 1.5%*			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	14.1%	12.5%	- 1.6%	*13.8%*	*15.2%*	*1.4%*			

Continued

Appendix 3. Recovery rates of Fraser River sockeye salmon in high and low stress categories, and the fraction of tagged and untagged sockeye salmon that spawned fully, in mark recapture studies from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes	Difference	No	Yes	Difference	Yes	No	Difference
Shuswap System: females									
1994	26.3%	20.0%	- 6.3%	0.0%	0.0%	0.0%	*98.4%*	*99.5%*	*1.1%*
1995	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-
1997	-	-	-	-	-	-	-	-	-
1998	20.0%	0.0%	-20.0%	*19.8%*	*27.5%*	*7.7%*	*96.7%*	*92.6%*	*- 4.1%*
Shuswap System: males									
1994	*33.2%*	*31.6%*	*- 1.7%*	*0.0%*	*0.0%*	*0.0%*			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	21.8%	33.3%	11.6%	*21.8%*	*20.0%*	*- 1.8%*			
Shuswap System: pooled									
1994	*30.0%*	*29.2%*	*- 0.8%*	*0.0%*	*0.0%*	*0.0%*			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	-	-	-	-	-	-			
1998	21.0%	28.6%	7.6%	*20.9%*	*23.5%*	*2.6%*			
Stellako River: females									
1994	*33.6%*	*30.8%*	*- 2.8%*	0.0%	-	-	*91.7%*	*89.0%*	*- 2.6%*
1995	*30.0%*	*20.8%*	*- 9.2%*	0.0%	-	-	*65.7%*	*74.9%*	*9.2%*
1996	*32.1%*	*56.0%*	*23.9%*	0.0%	-	-	*93.2%*	*93.4%*	*0.3%*
1997	-	-	-	-	-	-	-	-	-
1998	35.5%	0.0%	-35.5%	0.0%	-	-	*95.4%*	*98.4%*	*3.0%*
Stellako River: males									
1994	*24.7%*	*16.7%*	*- 8.0%*	0.0%	-	-			
1995	*42.2%*	*22.7%*	*-19.5%*	0.0%	-	-			
1996	*30.3%*	*35.5%*	*5.2%*	0.0%	-	-			
1997	-	-	-	-	-	-			
1998	52.4%	0.0%	-52.4%	0.0%	-	-			
Stellako River: pooled									
1994	*31.0%*	*26.3%*	*- 4.7%*	0.0%	-	-			
1995	*37.3%*	*21.7%*	*-15.5%*	0.0%	-	-			
1996	*31.4%*	*44.6%*	*13.3%*	0.0%	-	-			
1997	-	-	-	-	-	-			
1998	42.3%	0.0%	-42.3%	0.0%	-	-			

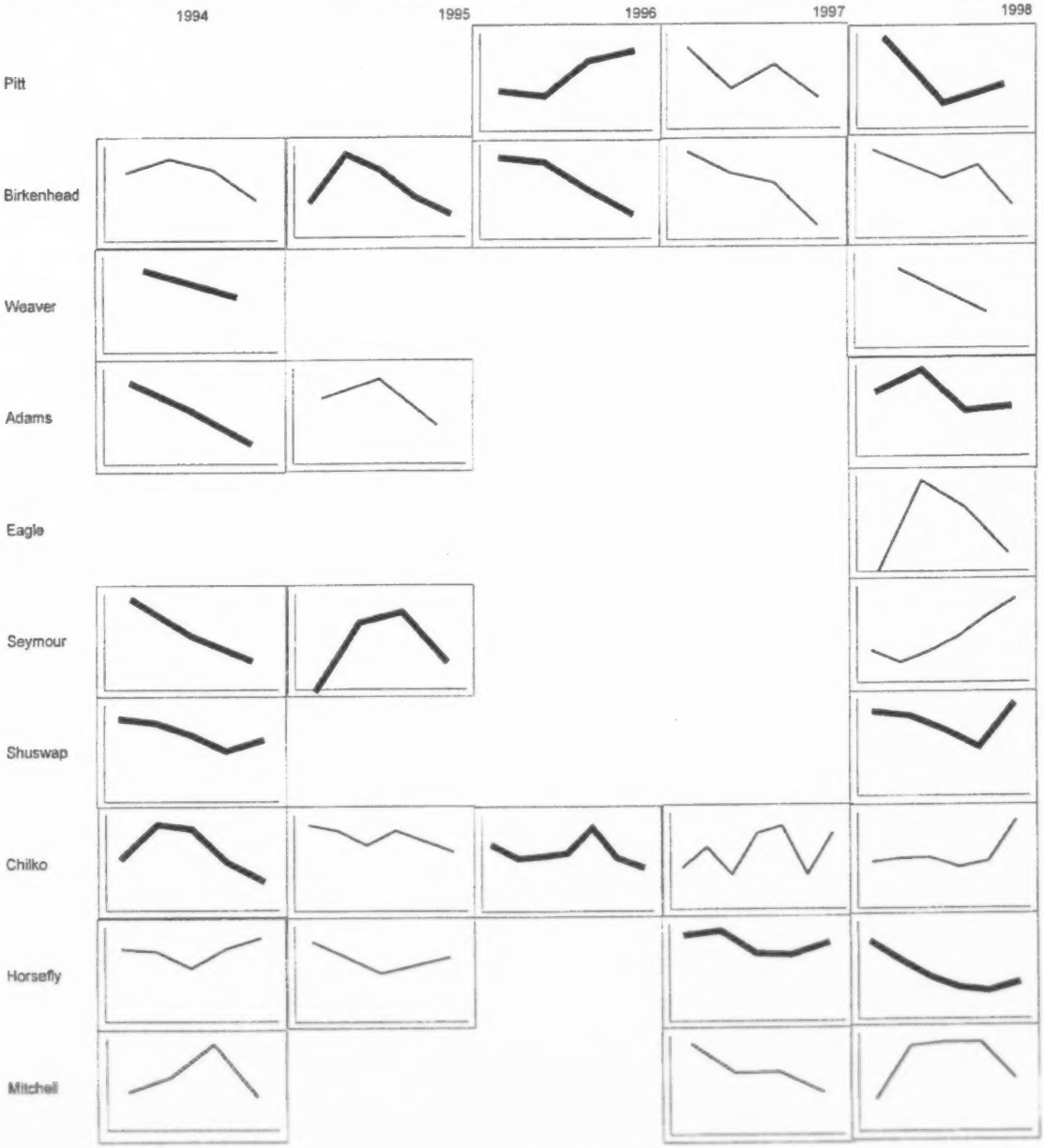
Continued

Appendix 3. Recovery rates of sockeye salmon in high and low stress categories, and fraction of tagged and untagged sockeye salmon which spawned fully, in mark recapture studies, from 1994 to 1998. Italics indicate cases with N>10 in the high stress category.

	Recovery rates						Fraction completely spawned		
	Required ventilation upon release?			Recaptured?			Tagged?		
Year	No	Yes		No	Yes		Yes	No	
Tachie River: females									
1994	18.3%	27.3%	9.0%	17.7%	20.7%	3.0%	-	-	-
1995	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-
1997	20.3%	14.3%	- 6.0%	17.2%	20.7%	3.5%	85.9%	87.2%	1.3%
1998	15.4%	40.0%	24.6%	16.4%	11.4%	- 4.9%	98.2%	98.3%	0.1%
Tachie River: males									
1994	19.4%	17.9%	- 1.6%	19.1%	21.7%	2.6%			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	18.0%	15.8%	- 2.2%	13.9%	23.6%	9.7%			
1998	12.7%	0.0%	-12.7%	11.8%	18.2%	6.3%			
Tachie River: pooled									
1994	18.8%	22.0%	3.2%	18.3%	21.3%	2.9%			
1995	-	-	-	-	-	-			
1996	-	-	-	-	-	-			
1997	19.4%	15.0%	- 4.4%	15.9%	22.2%	6.3%			
1998	14.2%	22.2%	8.0%	14.3%	14.0%	- 0.3%			
Weaver Creek: females									
1994	21.2%	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-
1996	38.1%	50.0%	11.9%	38.2%	37.5%	- 0.7%	50.8%	-	-
1997	-	-	-	-	-	-	-	-	-
1998	43.4%	50.0%	6.6%	43.7%	100.0%	56.3%	79.1%	89.4%	10.3%
Weaver Creek: males									
1994	26.6%	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	50.1%	75.0%	24.9%	50.7%	26.3%	-24.4%			
1997	-	-	-	-	-	-			
1998	55.3%	66.7%	11.4%	56.1%	100.0%	43.9%			
Weaver Creek: pooled									
1994	24.0%	-	-	-	-	-			
1995	-	-	-	-	-	-			
1996	45.0%	66.7%	21.6%	45.4%	29.6%	-15.8%			
1997	-	-	-	-	-	-			
1998	49.2%	57.7%	8.5%	49.7%	100.0%	50.3%			

Appendix 4. Spatial patterns of tag incidence in Fraser River sockeye mark-recapture programs, between 1994 and 1998. Figures with a thick line represent cases in which a chi-square test of the effect of recovery area on tag incidence (spatial application bias test) was significant. The x-axis represents recovery areas moving upstream from left to right.

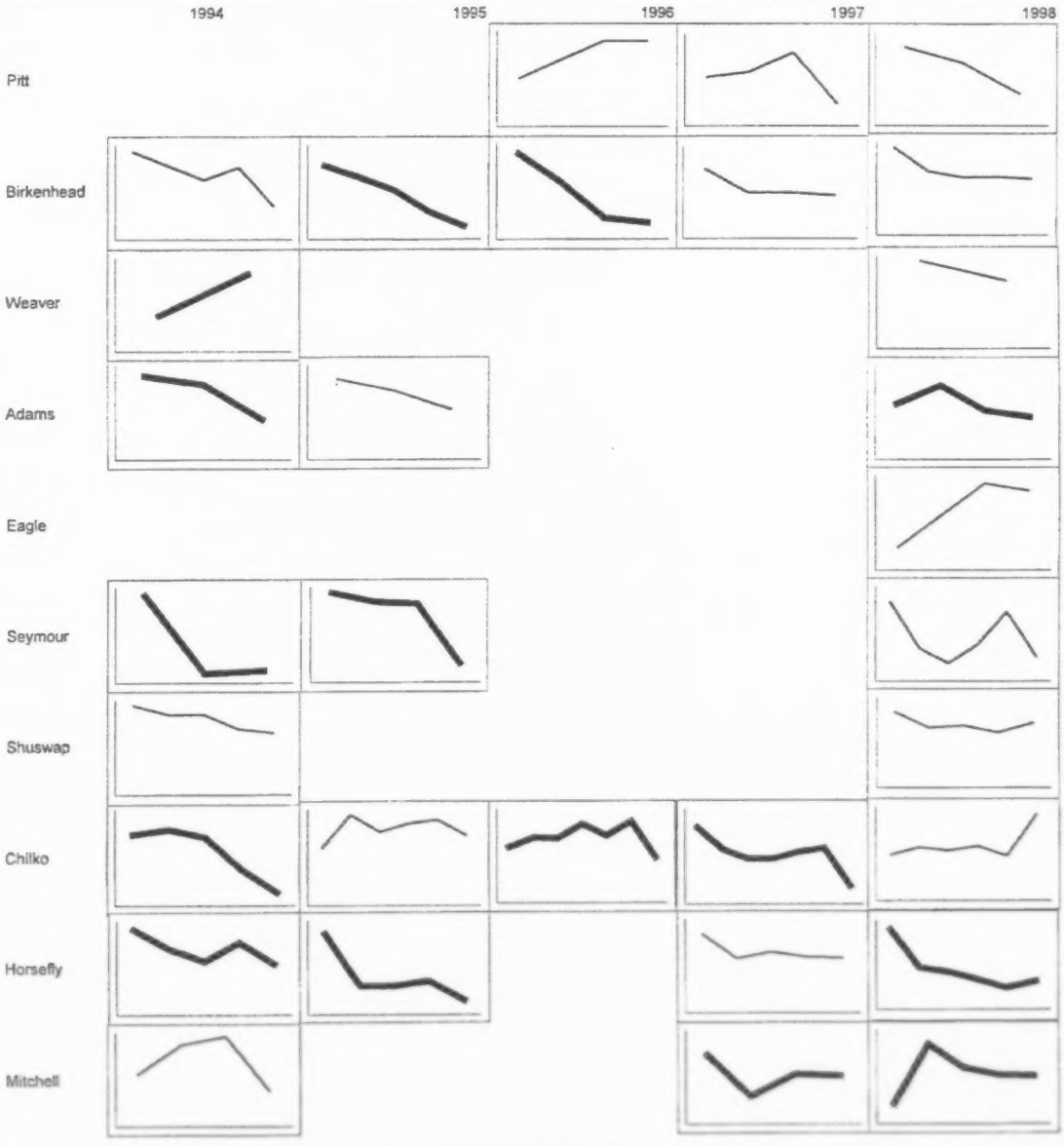
Females



Continued

Appendix 4. Spatial patterns of tag incidence in Fraser River sockeye mark-recapture programs, between 1994 and 1998. Figures with a thick line represent cases in which a chi-square test of the effect of recovery area on tag incidence (spatial application bias test) was significant. X-axis represents recovery areas moving upstream from left to right.

Males



Middle — Not available

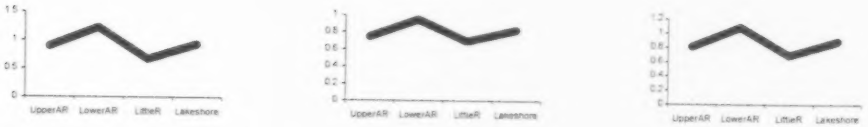
Tachie — Not available

Appendix 5. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

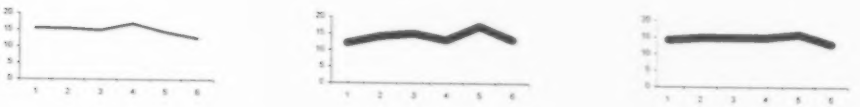
Adams

MALE FEMALE POOLED

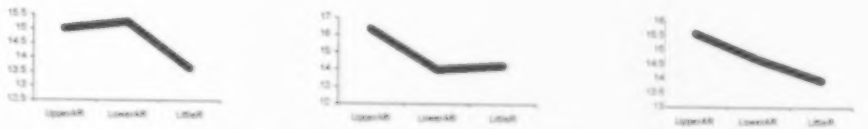
Tag Incidence vs Recovery Period



Tag Incidence vs Recovery Area



Recovery rate vs Application Period

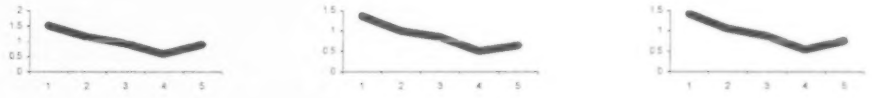


Recovery rate vs tagging area

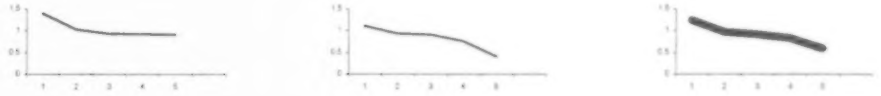
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Birkenhead

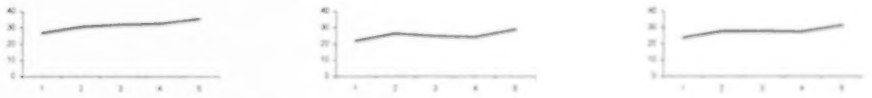
MALE FEMALE POOLED



Tag Incidence vs Recovery Period



Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE

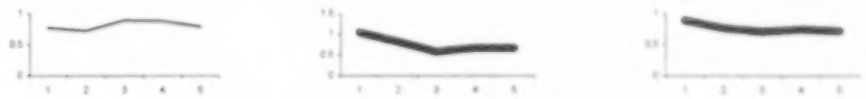
Recovery rate vs spawning area (best guess)*

* The guess was based on the following logic: i) Except for the bottom reaches, the river morphology is quite consistent over the extent of spawning, with carcasses relatively likely to become available to recovery- in the bottom reach, the river deepens and slows, with riprap banks, probably resulting in lower recoverability of carcasses (approximately 10-20% of the population spawned low enough to have experienced this lower recovery rate), and ii) Recovery effort was quite evenly applied spatially.

Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

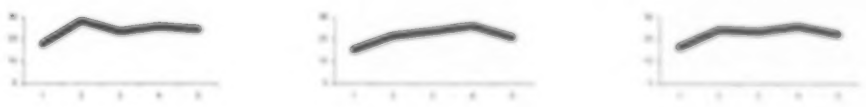
Chilko

MALE FEMALE POOLED



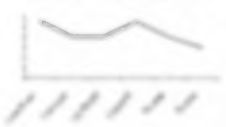
Tag Incidence vs Recovery Period

Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



Recovery rate vs spawning area (best guess) *

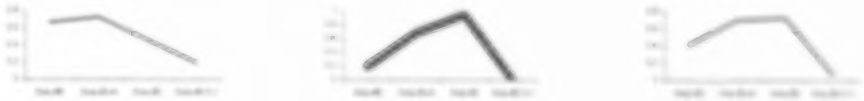
* The guess was based on the following logic: the lower and upper river morphology lends itself best to recovery. In canoe crossing, the river is slow and broad, with probable low recoverability of fish spawning there and the larger number of fish spawning in the area just above ("upper/mid"). In the lake, carcasses are relatively unlikely to come to shore. Recovery rates for south lake spawners are probably lower than north lake because the shores of the south lake are mostly steeply sloped unlike the north lake (gravel shoreline common).

Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Eagle

MALE FEMALE POOLED

Tag Incidence vs Recovery Period



Tag Incidence vs Recovery Area

Recovery rate vs Application Period

MALE & FEMALE

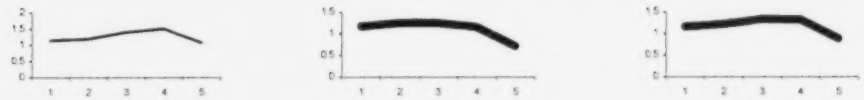
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: The upper river had lower volume and lower turbidity, and was shallower, and thus had a higher recovery probability than the lower river.

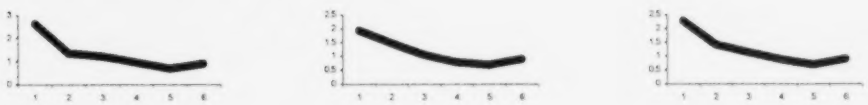
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Horsefly

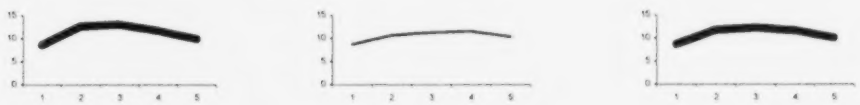
MALE FEMALE POOLED



Tag Incidence vs Recovery Period

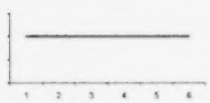


Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



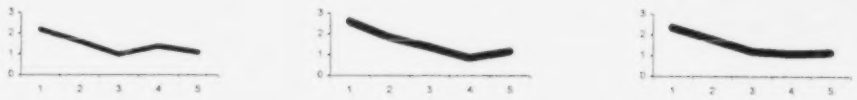
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: i) a small (<10%) of spawning occurs within 1 km upstream of the two major unrecoverable carcass sinks (Quesnel Lake and the meandering reach in the mid-river), ii) the river volume is similar throughout the length of spawning, iii) recovery effort was very consistently applied spatially.

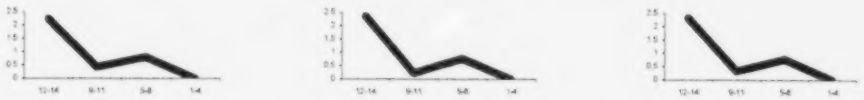
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Middle

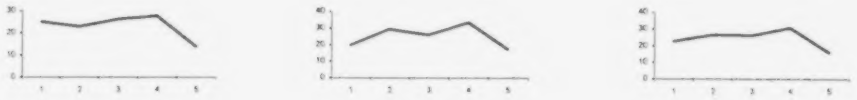
MALE FEMALE POOLED



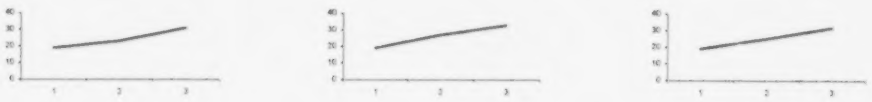
Tag Incidence vs Recovery Period



Tag Incidence vs Recovery Area



Recovery rate vs Application Period

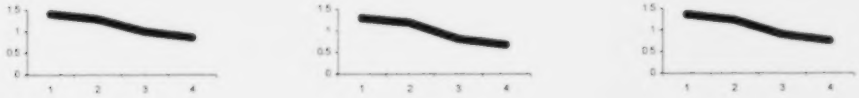


Recovery rate vs spawning area

Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

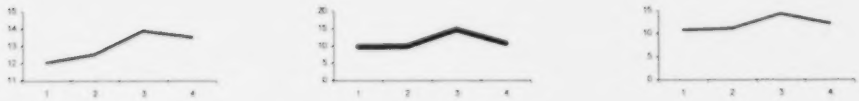
Mitchell

MALE FEMALE POOLED



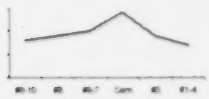
Tag Incidence vs Recovery Period

Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



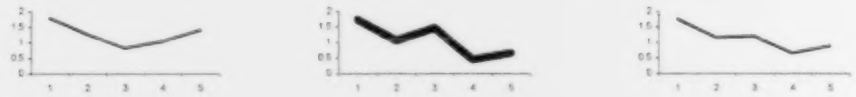
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: i) The bottom end of the river is slow and deeper than the rest of river. Cameron creek had high recovery rate due to its small volume. Near the bottom of area 5, a canyon probably acted as a carcass sink for area five spawners. Access to reaches 1-4 was difficult, resulting in less frequent and extensive surveys than in the rest of the river. Approximately 75% of spawning occurred in the Mitchell River itself from reach 5 to 7.

Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Pitt

MALE FEMALE POOLED

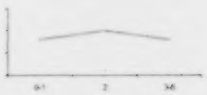


Tag Incidence vs Recovery Period

Tag Incidence vs Recovery Area

Recovery rate vs Application Period

MALE & FEMALE



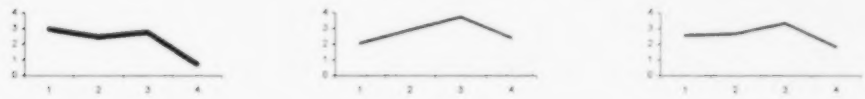
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: The majority of area 2 spawners spawn in Corbold Creek where recovery rates should be relatively high due to the lower volume of the creek.

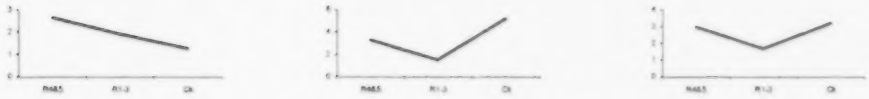
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Seymour

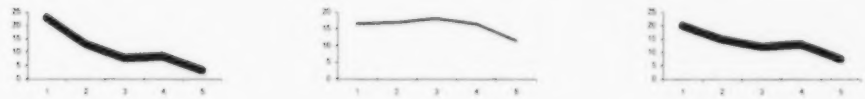
MALE FEMALE POOLED



Tag Incidence vs Recovery Period

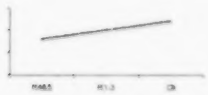


Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



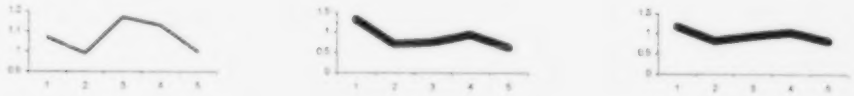
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: i) Reach 4 and 5 are slower and deeper than reaches 1-3, and carcasses dying there have less distance to become recoverable. ii) This difference in recovery probability between lower (R5&4) and upper (R1-3) river spawners is known to have existed in 1995 when fish were tagged in both areas. iii) McNomee Creek is low volume and therefore, a high fraction of carcasses probably become available to recovery.

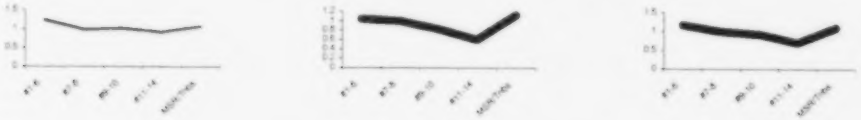
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Shuswap

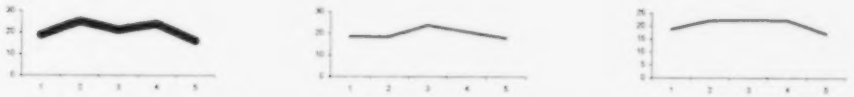
MALE FEMALE POOLED



Tag Incidence vs Recovery Period

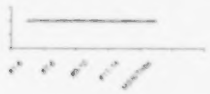


Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



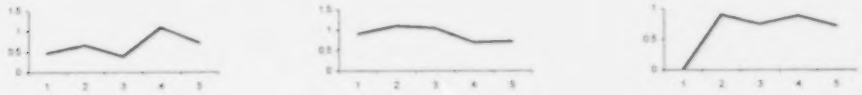
Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: i) The morphology and volume of the lower and middle Shuswap are quite consistent through most of the study area. ii) Spawners upstream of two areas with probable low recovery probabilities (reach 4 & 5, canyon in reach 11) are seperated from these areas by several hundred meters with high recoverability. iii) Recovery effort was evenly applied throughout the study area.

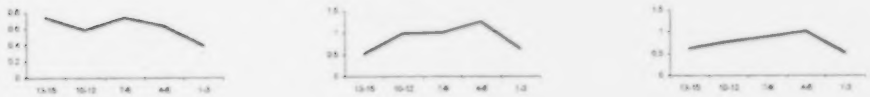
Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Tachie

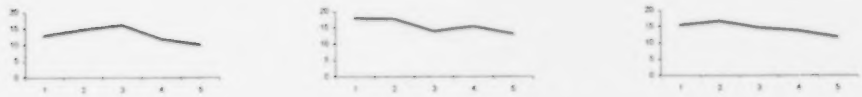
MALE FEMALE POOLED



Tag Incidence vs Recovery Period

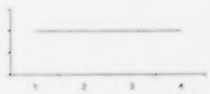


Tag Incidence vs Recovery Area



Recovery rate vs Application Period

MALE & FEMALE



Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: i) the river morphology was quite constant throughout the study area, and ii) recovery effort was quite evenly applied.

NOTE: All tests had low power; thus, significant sampling biases could be present

Appendix 5, continued. Application and recovery sampling profiles in the 1998 mark recapture studies of sockeye salmon. Thick lines represent significant test results ($p<0.05$, chi-square test). The x-axis represents time periods (temporal patterns) or areas (spatial patterns); from left to right, recovery periods are ordered from the start to the end of the program, while areas are ordered from downstream up (unless area names are given).

Weaver

MALE FEMALE POOLED

Tag Incidence vs Recovery Period

Tag Incidence vs Recovery Area

Recovery rate vs Application Period

MALE & FEMALE

Recovery rate vs spawning area (best guess) *

* The guess was based on the following logic: The mark-recapture study area is so small, with spawning extending for approx. 800m upstream of Morris Lake, that recovery rates probably had little opportunity to vary spatially.

Appendix 6. Mean daily sockeye counts during 15-minute index periods at towers or bridge crossings in the Adams, Lower Shuswap, Chilko and Quesnel rivers, 1998.

	Lower Adams River West Channel Tower		Lower Adams River East Channel Tower		Lower Shuswap River Enderby Bridge		Chilko River Henry's Bridge		Quesnel River Likely Bridge	
Date	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count
1-Aug	-	-	-	-	-	-	8	1	8	0
2-Aug	-	-	-	-	-	-	8	0	8	0
3-Aug	-	-	-	-	-	-	8	0	8	0
4-Aug	-	-	-	-	-	-	8	0	8	0
5-Aug	-	-	-	-	-	-	8	1	8	3
6-Aug	-	-	-	-	-	-	9	0	8	5
7-Aug	-	-	-	-	-	-	9	0	8	6
8-Aug	-	-	-	-	-	-	14	0	8	3
9-Aug	-	-	-	-	-	-	14	0	8	8
10-Aug	-	-	-	-	-	-	14	1	8	4
11-Aug	-	-	-	-	-	-	14	10	8	3
12-Aug	-	-	-	-	-	-	14	5	8	6
13-Aug	-	-	-	-	-	-	14	13	8	5
14-Aug	-	-	-	-	-	-	14	9	8	15
15-Aug	-	-	-	-	-	-	14	6	8	13
16-Aug	-	-	-	-	-	-	14	10	8	65
17-Aug	-	-	-	-	-	-	14	29	8	154
18-Aug	-	-	-	-	-	-	14	95	8	107
19-Aug	-	-	-	-	-	-	14	165	8	84
20-Aug	-	-	-	-	-	-	14	152	8	52
21-Aug	-	-	-	-	-	-	14	238	8	38
22-Aug	-	-	-	-	-	-	14	61	8	107
23-Aug	-	-	-	-	-	-	14	316	8	151
24-Aug	-	-	-	-	-	-	14	247	8	399
25-Aug	-	-	-	-	-	-	14	137	8	550
26-Aug	-	-	-	-	-	-	14	249	8	372
27-Aug	-	-	-	-	-	-	14	306	8	251
28-Aug	-	-	-	-	-	-	14	479	8	122
29-Aug	-	-	-	-	-	-	14	287	8	148
30-Aug	-	-	-	-	-	-	14	196	8	184
31-Aug	1 [B]	0	-	-	-	-	14	213	8	263
1-Sep	1 [B]	0	-	-	-	-	14	167	8	239
2-Sep	1 [B]	9	-	-	-	-	14	283	8	146
3-Sep	1 [B]	1	-	-	-	-	14	220	8	137
4-Sep	1 [B]	1	-	-	-	-	14	309	8	160
5-Sep	1 [B]	0	-	-	-	-	14	265	8	224
6-Sep	1 [B]	2	-	-	-	-	14	170	8	309
7-Sep	1 [B]	15	-	-	-	-	14	235	8	206
8-Sep	-	-	-	-	-	-	14	296	8	230
9-Sep	-	-	-	-	-	-	14	424	8	201
10-Sep	1 [B]	5	-	-	-	-	14	413	8	171
11-Sep	2 [B]	417	-	-	-	-	14	500	8	109
12-Sep	3 [B]	353	-	-	-	-	14	197	8	75
13-Sep	8 [B]	557	-	-	-	-	14	160	8	74
14-Sep	-		-	-	-	-	14	114	8	42
15-Sep	-		-	-	-	-	14	76	8	57
16-Sep	-		-	-	-	-	14	65	8	34
17-Sep	6 [B]	303	-	-	-	-	14	46	8	18
18-Sep	8 [B]	1,084	-	-	-	-	14	40	8	16

Continued

Appendix 6. Mean daily sockeye counts during 15-minute index periods at towers or bridge crossings in the Adams, Lower Shuswap, Quesnel and Chilko rivers, 1998 continued.

	Lower Adams River West Channel Tower		Lower Adams River East Channel Tower		Lower Shuswap River Enderby Bridge		Chilko River Henry's Bridge		Quesnel River Likely Bridge	
Date	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count	Number of counts per day [A]	Mean sockeye count
19-Sep	-	-	-	-	-	-	14	23	8	12
20-Sep	-	-	-	-	-	-	14	29	8	7
21-Sep	-	-	-	-	-	-	14	18	8	6
22-Sep	10	0	20	1	-	-	14	19	8	6
23-Sep	11	2	25	5	-	-	14	19	8	10
24-Sep	6	1	11	5	-	-	14	12	8	8
25-Sep	7	0	15	32	-	-	14	9	8	7
26-Sep	6	83	16	169	-	-	14	5	8	3
27-Sep	11	109 [C]	23	64	-	-	14	11	8	2
28-Sep	5	133	14	249	16	2	14	8	8	1
29-Sep	7	62	16	515	16	28	14	3	8	1
30-Sep	6	163	15	779	16	62	14	2	8	1
1-Oct	8	246	16	1,126	16	225	14	7	-	-
2-Oct	8	61	15	132	16	304	14	3	-	-
3-Oct	8	351	15	623	16	554	14	2	-	-
4-Oct	8	475	16	880	16	609	-	-	-	-
5-Oct	8	249	16	209	16	594	-	-	-	-
6-Oct	8	205	16	455	16	254	-	-	-	-
7-Oct	8	33	16	24	20	311	-	-	-	-
8-Oct	8	53	16	21	17	120	-	-	-	-
9-Oct	7	58	16	16	16	55	-	-	-	-
10-Oct	8	43	15	48	16	56	-	-	-	-
11-Oct	8	46	16	128	16	73	-	-	-	-
12-Oct	8	110	16	382	16	32	-	-	-	-
13-Oct	7	156	16	865	16	32	-	-	-	-
14-Oct	8	67	16	239	15	26	-	-	-	-
15-Oct	8	78	16	157	16	18	-	-	-	-
16-Oct	8	109	16	93	16	12	-	-	-	-
17-Oct	8	101	15	249	16	6	-	-	-	-
18-Oct	8	72	15	95	16	4	-	-	-	-
19-Oct	8	80	16	102	16	0	-	-	-	-
20-Oct	7	59	16	239	16	1	-	-	-	-
21-Oct	8	56	16	80	16	1	-	-	-	-
22-Oct	8	30	15	77	16	0	-	-	-	-
23-Oct	7	30	15	111	16	1	-	-	-	-
24-Oct	8	16	16	21	16	0	-	-	-	-
25-Oct	7	15	16	71	-	-	-	-	-	-
26-Oct	7	23	16	163	-	-	-	-	-	-
27-Oct	8	22	16	126	-	-	-	-	-	-
28-Oct	7	18	16	25	-	-	-	-	-	-
29-Oct	8	16	16	24	-	-	-	-	-	-
30-Oct	8	20	16	24	-	-	-	-	-	-
31-Oct	7	3	15	4	-	-	-	-	-	-

[A] Fifteen minute counts every half hour.

[B] Initial counts were at the Squalax Bridge across Little River.

[C] Jet boats and scuba divers disrupted migration

Appendix 7. Daily sockeye counts at enumeration fences constructed in the Fraser River system, 1998.

							Early Stuart Group			
Date	Eagle River [A]	Kuzkwa Creek	McKinley Creek	Scotch Creek [B]	Salmon River [B]	Stellako River	Forfar Creek	Gluske Creek	Kynoch Creek	Sweltzer Creek
14-Jul	-	-	-	-	-		-	-	-	-
15-Jul	-	-	-	-	-		-	-	-	-
16-Jul	-	-	-	-	-		-	0	-	-
17-Jul	-	-	-	-	-		0	0	-	-
18-Jul	-	-	-	-	-	-	0	0	0	-
19-Jul	-	-	-	-	-	-	0	0	0	-
20-Jul	-	-	-	-	-	-	0	0	0	-
21-Jul	-	-	-	-	-	-	0	0	2	-
22-Jul	-	-	-	-	-	-	0	0	88 [C]	-
23-Jul	-	-	-	-	-	-	0	9	399	-
24-Jul	-	-	-	-	-	-	16	19	244	-
25-Jul	-	-	-	-	-	-	3	184	18	-
26-Jul	-	-	-	-	-	-	0	43	183	-
27-Jul	-	-	-	-	-	-	97	44	219	-
28-Jul	-	-	-	-	-	-	49	52	128	-
29-Jul	-	-	-	-	-	-	2	40	213	-
30-Jul	-	-	-	-	-	-	101	33	63	-
31-Jul	-	-	-	-	-	-	55	75	58	-
1-Aug	-	-	-	-	-	-	33	37	37	-
2-Aug	-	-	-	-	-	-	86	42	44	-
3-Aug	-	-	-	-	-	-	47	21	100	-
4-Aug	-	-	-	-	-	-	105	21	98	-
5-Aug	-	-	-	-	-	-	29	85	19	-
6-Aug	-	-	-	-	-	-	70	18	38	-
7-Aug	-	-	-	-	-	-	75	7	39	-
8-Aug	-	-	-	-	-	-	2	19	30	-
9-Aug	-	-	-	-	-	-	33	12	69	-
10-Aug	-	-	-	-	-	-	8	25	56	-
11-Aug	-	-	-	-	-	-	14	5	1	-
12-Aug	-	-	-	-	-	-	64	11	57	-
13-Aug	-	-	-	-	-	-	52	4	35	-
14-Aug	-	-	-	0	-	-	12	3	13	-
15-Aug	-	-	-	2	-	-	-1	2	14	-
16-Aug	-	-	-	61	-	-	4	1	3	-
17-Aug	-	-	-	2,174	-	-	-2	0	0	-
18-Aug	-	-	-	1,713	-	13	2	0	2	-
19-Aug	-	-	-	856	-	17	-	0	-	-
20-Aug	-	-	-	1,023	-	20	-	0	-	-
21-Aug	-	-	-	889	-	169	-	0	-	-
22-Aug	-	-	-	3,623	-	349	-	0	-	-
23-Aug	-	-	-	3,782	-	197	-	-	-	-
24-Aug	-	-	3,214	2,999	-	205	-	-	-	-
25-Aug	-	-	3,859	2,966	-	38	-	-	-	-
26-Aug	-	-	2,216	3,654	-	56	-	-	-	-
27-Aug	-	-	5,756	3,334	-	38	-	-	-	-
28-Aug	-	-	5,746	833	-	118	-	-	-	-
29-Aug	-	-	6,399	1,187	-	732	-	-	-	-
30-Aug	-	-	4,419	1,227	-	84	-	-	-	-
31-Aug	-	-	2,322	655	-	1,650	-	-	-	-
1-Sep	-	-	8,355	1,184	-	24	-	-	-	-
2-Sep	-	-	4,621	861	-	393	-	-	-	-
3-Sep	-	-	2,309	599	-	355	-	-	-	-
4-Sep	-	-	2,778	607	-	23	-	-	-	-
5-Sep	-	0	2,637	1,082	-	46	-	-	-	-
6-Sep	-	8	3,724	337	-	1,373	-	-	-	-
7-Sep	-	14	2,578	19	-	5,511	-	-	-	-
8-Sep	-	0	1,868	158	-	17,402	-	-	-	-

Continued

Appendix 7. Daily sockeye counts at enumeration fences constructed in the Fraser River system, 1998 continued.

							Early Stuart Group			
Date	Eagle River [A]	Kuzkwa Creek	McKinley Creek	Scotch Creek	Salmon River [B]	Stellako River	Forfar Creek	Gluske Creek	Kynoch Creek	Sweltzer Creek
9-Sep	-	0	1,504	16	-	17,642	-	-	-	-
10-Sep	-	28	1,789	55	-	21,166	-	-	-	-
11-Sep	-	0	2,677	30	-	12,294	-	-	-	-
12-Sep	-	0	1,935	31	-	8,624	-	-	-	-
13-Sep	-	1297	1,813	11	-	10,620	-	-	-	-
14-Sep	-	1	1,087	0	-	8,939	-	-	-	6
15-Sep	-	0	602	-	-	3,068	-	-	-	2
16-Sep	-	2	418	-	-	5,854	-	-	-	3
17-Sep	-	154	406	-	-	14,620	-	-	-	3
18-Sep	-	489	238	-	-	8,822	-	-	-	2
19-Sep	-	193	108	-	-	9,561	-	-	-	3
20-Sep	-	164	100	-	-	10,720	-	-	-	7
21-Sep	-	60	74	-	-	5,130	-	-	-	19
22-Sep	-	401	88	-	-	3,184	-	-	-	7
23-Sep	-	11	58	-	-	1,756	-	-	-	9
24-Sep	-	11	71	-	-	986	-	-	-	7
25-Sep	-	0	56	-	-	2,670	-	-	-	11
26-Sep	-	24	1	-	-	1,439	-	-	-	21
27-Sep	-	7	0	-	-	1,364	-	-	-	62
28-Sep	-	3	3	-	-	772	-	-	-	13
29-Sep	-	0	0	-	-	1,092	-	-	-	6
30-Sep	-	0	0	-	-	935	-	-	-	6
1-Oct	206	0	-	-	-	622	-	-	-	22
2-Oct	501	0	-	-	-	650	-	-	-	10
3-Oct	844	0	-	-	-	626	-	-	-	7
4-Oct	1,707	0	-	-	-	1687	-	-	-	6
5-Oct	2,297	-	-	-	1	1239	-	-	-	7
6-Oct	836	-	-	-	-	1298	-	-	-	6
7-Oct	711	-	-	-	1	715	-	-	-	18
8-Oct	813	-	-	-	1	271	-	-	-	6
9-Oct	713	-	-	-	-	220	-	-	-	7
10-Oct	681	-	-	-	-	78	-	-	-	16
11-Oct	341	-	-	-	1	123	-	-	-	3
12-Oct	118	-	-	-	-	128	-	-	-	9
13-Oct	115	-	-	-	17	84	-	-	-	11
14-Oct	192	-	-	-	4	37	-	-	-	129
15-Oct	128	-	-	-	5	20	-	-	-	279
16-Oct	61	-	-	-	4	47	-	-	-	160
17-Oct	60	-	-	-	17	28	-	-	-	14
18-Oct	31	-	-	-	2	0	-	-	-	167
19-Oct	32	-	-	-	-	-	-	-	-	134
20-Oct	19	-	-	-	-	-	-	-	-	63
21-Oct	0	-	-	-	6	-	-	-	-	116
22-Oct	0	-	-	-	6	-	-	-	-	62
23-Oct	0	-	-	-	7	-	-	-	-	84
24-Oct	0	-	-	-	-	-	-	-	-	25
25-Oct	0	-	-	-	1	-	-	-	-	15
26-Oct	0	-	-	-	1	-	-	-	-	22
27-Oct	0	-	-	-	2	-	-	-	-	24
28-Oct	0	-	-	-	-	-	-	-	-	33
29-Oct	0	-	-	-	1	-	-	-	-	50
30-Oct	0	-	-	-	1	-	-	-	-	27
31-Oct	0	-	-	-	-	-	-	-	-	35
1-Nov	0	-	-	-	1	-	-	-	-	17
2-Nov	0	-	-	-	1	-	-	-	-	30
3-Nov	0	-	-	-	-	-	-	-	-	21
4-Nov	0	-	-	-	-	-	-	-	-	23

Continued

Appendix 7. Daily sockeye counts at enumeration fences constructed in the Fraser River system, 1998 continued.

							Early Stuart Group			
Date	Eagle River [A]	Kuzkwa Creek	McKinley Creek	Scotch Creek	Salmon River [B]	Stellako River	Forfar Creek	Gluske Creek	Kynoch Creek	Sweltzer Creek
5-Nov	0	-	-	-	1	-	-	-	-	19
6-Nov	0	-	-	-	-	-	-	-	-	20
7-Nov	0	-	-	-	-	-	-	-	-	58
8-Nov	0	-	-	-	-	-	-	-	-	11
9-Nov	0	-	-	-	-	-	-	-	-	8
10-Nov	92	-	-	-	-	-	-	-	-	8
11-Nov	0	-	-	-	-	-	-	-	-	10
12-Nov	0	-	-	-	-	-	-	-	-	33
13-Nov	0	-	-	-	-	-	-	-	-	38
14-Nov	-	-	-	-	-	-	-	-	-	25
15-Nov	-	-	-	-	-	-	-	-	-	22
16-Nov	-	-	-	-	-	-	-	-	-	10
17-Nov	-	-	-	-	-	-	-	-	-	11
18-Nov	-	-	-	-	-	-	-	-	-	7
19-Nov	-	-	-	-	-	-	-	-	-	5
20-Nov	-	-	-	-	-	-	-	-	-	3
21-Nov	-	-	-	-	-	-	-	-	-	1
22-Nov	-	-	-	-	-	-	-	-	-	0
23-Nov	-	-	-	-	-	-	-	-	-	0
24-Nov	-	-	-	-	-	-	-	-	-	-
25-Nov	-	-	-	-	-	-	-	-	-	-
26-Nov	-	-	-	-	-	-	-	-	-	-
27-Nov	-	-	-	-	-	-	-	-	-	-
28-Nov	-	-	-	-	-	-	-	-	-	-
29-Nov	-	-	-	-	-	-	-	-	-	-
30-Nov	-	-	-	-	-	-	-	-	-	-
Male	5,445 [E]	1,393	37,892 [D]	17,962 [D]	51	88,353 [F]	546 [D]	453 [D]	1,059 [D]	928 [D]
Female	5,053 [E]	1,471	37,937 [D]	17,994 [D]	27	99,535 [F]	407 [D]	358 [D]	1,207 [D]	1,031 [D]
Jack	0 [E]	3	0 [D]	12 [D]	0	56	3 [D]	1 [D]	4 [D]	175 [D]
Total	10,498	2,867	75,829	35,968	78	187,944	956	812	2,270	2,134

[A] Data provided by Habitat and Enhancement Branch.

[B] Data provided by Shuswap Nation Fisheries Commission.

[C] Fence breached, live count of 90 fish above fence.

[D] Sex ratio and jack composition estimated from carcass surveys upstream from the fence.

[E] From observations at the fence.

[F] Sex ratio was from the total carcass sample. Includes Nadina spawners; excludes pre-fence installation immigrants and below-fence spawners.

Appendix 8. Daily live counts, male, female and jack carcass recoveries, and female spawning success from the Gates, Nadina and Weaver spawning channels, 1998.

	Gates Creek Channel							Nadina River Channel						
		Carcasses recovered			% spawned				Carcasses recovered			% spawned		
Date	Live count	Male	Female	Jack	0%	50%	100%	Live count	Male	Female	Jack	0%	50%	100%
8-Aug	1	0	0	0	0	0	0	-	-	-	-	-	-	-
9-Aug	1	0	0	0	0	0	0	-	-	-	-	-	-	-
10-Aug	1	0	0	0	0	0	0	-	-	-	-	-	-	-
11-Aug	0	0	0	0	0	0	0	-	-	-	-	-	-	-
12-Aug	0	0	0	0	0	0	0	-	-	-	-	-	-	-
13-Aug	0	0	0	0	0	0	0	-	-	-	-	-	-	-
14-Aug	2	0	0	0	0	0	0	-	-	-	-	-	-	-
15-Aug	5	0	1	0	1	0	0	-	-	-	-	-	-	-
16-Aug	72	0	0	0	0	0	0	-	-	-	-	-	-	-
17-Aug	154	0	0	0	0	0	0	11	-	-	-	-	-	-
18-Aug	264	0	0	0	0	0	0	96	-	-	-	-	-	-
19-Aug	739	1	0	0	0	0	0	63	-	-	-	-	-	-
20-Aug	394	2	0	2	0	0	0	43	-	-	-	-	-	-
21-Aug	303	6	5	0	5	0	0	53	-	-	-	-	-	-
22-Aug	443	6	7	1	7	0	0	100	-	-	-	-	-	-
23-Aug	386	13	9	2	9	0	0	82	-	-	-	-	-	-
24-Aug	359	0	0	0	0	0	0	29	-	-	-	-	-	-
25-Aug	609	2	21	0	21	0	0	79	1	2	0	2	0	0
26-Aug	500	14	22	2	22	0	0	25	2	2	0	2	0	0
27-Aug	503	35	43	9	41	2	0	10	1	1	0	1	0	0
28-Aug	528	50	71	2	58	8	5	76	1	1	0	1	0	0
29-Aug	151	62	87	3	70	9	8	152	0	6	0	6	0	0
30-Aug	284	92	100	4	76	7	17	140	1	2	0	2	0	0
31-Aug	286	81	83	1	63	15	5	139	1	2	0	2	0	0
1-Sep	305	82	143	17	72	16	55	75	2	3	0	3	0	0
2-Sep	182	147	234	22	84	36	114	32	2	1	0	1	0	0
3-Sep	301	197	189	31	60	32	97	123	1	1	0	1	0	0
4-Sep	200	175	234	34	79	28	127	66	0	2	0	2	0	0
5-Sep	54	170	200	39	67	25	108	210	1	1	0	1	0	0
6-Sep	41	171	232	49	67	33	132	230	2	1	0	1	0	0
7-Sep	40	188	257	73	83	36	138	173	0	2	0	2	0	0
8-Sep	-	194	228	56	69	30	129	142	3	0	1	0	0	0
9-Sep	-	125	169	73	38	23	108	117	0	4	0	4	0	0
10-Sep	-	103	194	103	39	25	130	47	1	2	0	2	0	0
11-Sep	-	89	175	109	28	24	123	28	0	1	1	1	0	0
12-Sep	-	63	175	125	32	16	127	121	2	4	0	3	0	1
13-Sep	-	80	185	159	24	16	145	33	1	1	0	1	0	0
14-Sep	-	54	207	164	36	21	150	51	3	1	0	1	0	0
15-Sep	-	40	118	102	18	16	84	317	3	2	0	1	0	1
16-Sep	-	39	103	74	6	6	91	35	2	3	0	2	0	1
17-Sep	-	27	85	88	13	6	66	66	1	3	0	2	0	1
18-Sep	-	18	60	76	3	2	55	-	9	9	2	2	0	7
19-Sep	-	15	79	71	16	0	63	-	7	13	0	4	0	9
20-Sep	-	2	6	7	0	0	6	-	15	19	1	2	0	17
21-Sep	-	1	7	19	1	2	4	-	22	21	2	1	0	20
22-Sep	-	3	9	15	2	0	7	-	41	31	1	0	0	31
23-Sep	-	0	1	10	1	0	0	-	42	55	1	0	0	55
24-Sep	-	-	-	-	-	-	-	-	54	55	0	0	0	55
25-Sep	-	-	-	-	-	-	-	-	48	57	2	0	0	57
26-Sep	-	-	-	-	-	-	-	-	99	106	0	0	0	106
27-Sep	-	-	-	-	-	-	-	-	105	102	0	0	0	102
28-Sep	-	-	-	-	-	-	-	-	92	119	0	0	0	119
29-Sep	-	-	-	-	-	-	-	-	55	69	0	0	0	69
30-Sep	-	-	-	-	-	-	-	-	68	101	0	0	0	101

Continued

Appendix 8. Daily live counts, male, female and jack carcass recoveries, and female spawning success from the Gates, Nadina and Weaver spawning channels, 1998, continued.

	Gates Creek Channel							Nadina River Channel						
		Carcasses recovered			% spawned				Carcasses recovered			% spawned		
Date	Live count	Male	Female	Jack	0%	50%	100%	Live count	Male	Female	Jack	0%	50%	100%
1-Oct	-	-	-	-	-	-	-	-	93	111	0	0	0	111
2-Oct	-	-	-	-	-	-	-	-	48	82	0	0	0	82
3-Oct	-	-	-	-	-	-	-	-	22	42	0	0	0	42
4-Oct	-	-	-	-	-	-	-	-	0	0	0	0	0	0
5-Oct	-	-	-	-	-	-	-	-	40	81	0	0	0	81
6-Oct	-	-	-	-	-	-	-	-	13	27	0	0	0	27
7-Oct	-	-	-	-	-	-	-	-	9	21	0	0	0	21
8-Oct	-	-	-	-	-	-	-	-	18	17	0	0	0	17
9-Oct	-	-	-	-	-	-	-	-	14	15	0	0	0	15
10-Oct	-	-	-	-	-	-	-	-	0	0	0	0	0	0
11-Oct	-	-	-	-	-	-	-	-	9	11	0	0	0	11
12-Oct	-	-	-	-	-	-	-	-	3	4	0	0	0	4
Total	-	2,347	3,739	1,542 [A]	1,211	434	2,094	2,964 [B]	957	1,216	11	53	0	1,554

[A] Carcasses recoveries not adjusted for age misidentification.
[B] Dead recovery terminated before die-off was complete; total live count was used as the escapement estimate.

Appendix 8. Daily live counts, male, female and jack carcass recoveries and female spawning success from the Gates, Nadina, and Weaver spawning channels, 1998, continued.

	Weaver Creek Channel						
		Carcasses recovered			% spawned		
Date	Live count	Male	Female	Jack	0%	50%	100%
3-Oct	1,991	-	-	-	-	-	-
4-Oct	2,920	-	-	-	-	-	-
5-Oct	3,891	-	-	-	-	-	-
6-Oct	507	-	-	-	-	-	-
7-Oct	500	-	-	-	-	-	-
8-Oct	500	-	-	-	-	-	-
9-Oct	1,003	103	134	3	52	14	68
10-Oct	74	238	357	4	87	11	259
11-Oct	1,008	208	402	3	39	3	360
12-Oct	1,111	488	930	2	39	3	888
13-Oct	2,002	792	1,640		39	5	1,596
14-Oct	2,087	724	1,257	1	22	2	1,233
15-Oct	5,372	913	1,374	1	38	6	1,330
16-Oct	3,720	695	828	3	9	2	817
17-Oct	3,206	563	445	2	27	7	411
18-Oct	-	218	385	1	37	7	341
19-Oct	-	463	571	4	61	6	504
20-Oct	-	327	555	4	62	8	485
21-Oct	-	733	1,642	4	133	16	1,493
22-Oct	-	995	2,123	3	104	21	1,998
23-Oct	-	1,335	2,170	2	63	16	2,091
24-Oct	-	1,398	1,463	3	39	12	1,412
25-Oct	-	1,101	713	5	9	0	704
27-Oct	-	402	344	3	0	0	344
1-Nov	-	34	5	1	-	-	5
Total	29,892	11,730	17,338	49 [A]	860	139	16,339

[A] Carcasses recoveries not adjusted for age misidentification.

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Lower Fraser	Chilliwack Lake	18-Aug	-	5	1	0	6	6	1	0	3
		25-Aug	-	2	17	0	19	25	10	2	5
		31-Aug	-	31	33	0	64	89	17	1	11
		4-Sep	-	32	45	0	77	166	9	3	25
		11-Sep	-	39	62	1	102	268	5	2	39
	Nahatlatch Lake	26-Aug	1	16	18	0	34	34	15	2	1
		2-Sep	-	54	59	0	113	147	27	2	12
		8-Sep	1	47	41	0	88	235	9	4	20
	Nahatlatch River	27-Aug	2,875	7	10	0	17	17	10	0	0
		2-Sep	2,712	31	29	0	60	77	12	3	24
		9-Sep	3,437	23	33	0	56	133	2	4	21
		16-Sep	-	61	72	0	133	266	0	1	71
	Widgeon Slough	12-Nov	-	0	1	0	1	1	1	0	0
		18-Nov	34	3	1	0	4	5	0	0	1
		24-Nov	19	4	2	0	6	11	0	0	2
		1-Dec	4	4	1	0	5	16	0	0	1
Harrison-Lillooet	Big Silver Creek	15-Sep	2,414	15	12	0	27	27	7	1	3
		21-Sep	2,908	78	61	0	139	166	4	1	48
		23-Sep	3,018	70	68	0	138	304	6	2	48
		1-Oct	1,377	293	360	1	654	958	3	1	310
	Green River	25-Sep	0	0	0	0	0	0	0	0	0
	Harrison River	2-Nov	638	0	0	0	0	0	0	0	0
		9-Nov	2,482	10	6	0	16	16	0	0	5
		13-Nov	-	3	7	0	10	26	0	1	5
		16-Nov	627	7	9	0	16	42	1	0	8
		18-Nov	-	13	24	0	37	79	0	0	23
		23-Nov	-	39	61	0	100	179	0	1	53
		24-Nov	-	30	75	0	105	284	0	1	74
		30-Nov	-	24	82	0	106	390	0	0	82
	Poole Creek	21-Sep	117	0	0	0	0	0	0	0	0
		5-Oct	81	20	20	0	40	40	1	0	19
	Samson Creek	16-Sep	335	6	5	0	11	11	0	0	5
		24-Sep	318	12	21	0	33	44	1	2	18
		29-Sep	127	14	20	0	34	78	0	0	10
Seton-Anderson	Gates Creek [A]	17-Aug	8 [B]	0	0	0	0	0	0	0	0
		20-Aug	39	0	0	0	0	0	0	0	0
		22-Aug	0	0	1	0	1	1	1	0	0
		24-Aug	200	0	0	0	0	1	0	0	0
		27-Aug	99	0	0	0	0	1	0	0	0
		30-Aug	0	6	5	0	11	12	5	0	0
		1-Sep	47	2	1	0	3	15	0	0	1
		2-Sep	40	2	1	1	4	19	1	0	0
		3-Sep	87	0	0	0	0	19	0	0	0
		4-Sep	77	0	8	0	8	27	4	1	3
		7-Sep	0	20	0	0	20	47	0	0	0
		9-Sep	0	5	5	7	17	64	3	0	2
		10-Sep	0	4	0	0	4	68	0	0	0
		11-Sep	0	11	0	0	11	79	0	0	0
		14-Sep	0	33	9	9	51	130	1	0	8
		16-Sep	0	17	6	5	28	158	1	0	5
		19-Sep	500	0	0	0	0	158	0	0	0
	Portage Creek	28-Oct	13,491	0	0	0	512 [C]	512	0	0	0
		2-Nov	3,858	1,008	1,105	2	2,115	2,627	82	11	1,003
		6-Nov	-	777	812	1	1,590	4,217	60	19	648
		10-Nov	-	60	90	0	150	4,367	12	9	39

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
South	Adams Channel	24-Aug	0	0	0	0	0	0	0	0	0
Thompson		3-Sep	167	0	0	0	0	0	0	0	0
Early		5-Sep	219	0	0	0	0	0	0	0	0
Summer		10-Sep	173	3	7	0	10	10	3	0	4
Runs		14-Sep	62	0	0	0	0	10	0	0	0
		17-Sep	21	2	5	0	7	17	0	0	5
	Adams River, lower	26-Aug	76	0	0	0	0	0	0	0	0
		31-Aug	40	0	0	0	0	0	0	0	0
		2-Sep	98	0	0	0	0	0	0	0	0
		4-Sep	34	0	0	0	0	0	0	0	0
		5-Sep	843	7	5	0	12	12	0	0	5
		7-Sep	32	0	0	0	0	12	0	0	0
		9-Sep	9	0	3	0	3	15	0	0	3
		10-Sep	431	6	12	0	18	33	1	0	11
		14-Sep	39	0	0	0	0	33	0	0	0
		15-Sep	3	1	0	0	1	34	0	0	0
South	Adams River, upper	25-Aug	0	0	1	0	1	1	1	0	0
Thompson		2-Sep	86	1	2	0	3	4	0	0	2
Early		7-Sep	46	18	15	0	33	37	0	0	15
Summer		12-Sep	123	17	14	0	31	68	0	1	13
Runs		15-Sep	44	7	7	0	14	82	0	0	7
Continued	Anstey River	23-Aug	242	0	0	0	0	0	0	0	0
		29-Aug	2,082	1	1	0	2	2	0	0	1
		3-Sep	2,571	30	31	0	61	63	4	1	26
		8-Sep	1,782	115	83	0	198	261	6	0	77
		14-Sep	344	16	33	0	49	310	1	1	31
		16-Sep	0	39	51	0	90	400	1	0	50
	Cayenne Creek	18-Aug	0	0	0	0	0	0	0	0	0
		25-Aug	0	0	0	0	0	0	0	0	0
		2-Sep	86	2	2	0	4	4	0	0	2
		7-Sep	43	6	10	0	16	20	1	1	5
		12-Sep	2	0	2	0	2	22	0	0	2
	Celista Creek	31-Aug	0	0	0	0	0	0	0	0	0
		8-Sep	0	0	0	0	0	0	0	0	0
	Hiuihill Creek	26-Aug	185	11	3	0	14	14	2	1	0
		31-Aug	425	14	16	1	31	45	6	0	10
		5-Sep	405	97	55	0	152	197	4	1	50
		10-Sep	113	85	107	0	192	389	4	1	102
	Hunakwa Creek	29-Aug	0	0	0	0	0	0	0	0	0
		8-Sep	0	0	0	0	0	0	0	0	0
	Malakwa Creek	30-Aug	41	1	0	0	1	1	0	0	0
		2-Sep	31	4	4	0	8	9	1	0	3
		5-Sep	32	1	10	0	11	20	2	0	8
		8-Sep	10	1	9	0	10	30	0	0	8
		11-Sep	2	3	7	0	10	40	0	0	7
	McNomee Creek	24-Aug	23	0	0	0	0	0	0	0	0
		27-Aug	203	3	1	0	4	4	1	0	0
		30-Aug	358	8	2	0	10	14	0	0	0
		2-Sep	348	9	14	0	23	37	0	0	11
		5-Sep	327	17	13	0	30	67	3	0	9
		8-Sep	150	25	28	0	53	120	0	0	26
		11-Sep	50	8	12	0	20	140	0	1	8
		14-Sep	14	1	4	0	5	145	0	0	4
	Momich River	18-Aug	0	0	0	0	0	0	0	0	0
		2-Sep	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
	Nikwikwala Creek	21-Aug	0	0	0	0	0	0	0	0	0
		26-Aug	52	1	0	0	1	1	0	0	0
		31-Aug	78	0	1	0	1	2	1	0	0
		5-Sep	126	1	3	0	4	6	0	0	3
		10-Sep	57	0	2	0	2	8	0	0	2
	Onyx Creek [U]	21-Aug	0	0	0	0	0	0	0	0	0
	Perry River	28-Aug	30	0	0	0	0	0	0	0	0
		31-Aug	134	2	0	0	2	2	0	0	0
		3-Sep	296	0	4	0	4	6	0	0	4
		6-Sep	319	2	1	0	3	9	0	0	1
		9-Sep	-	13	21	0	34	43	0	0	21
		12-Sep	93	11	20	0	31	74	0	0	20
		15-Sep	-	6	16	0	22	96	0	0	16
		18-Sep	0	0	0	0	0	96	0	0	0
	Ross Creek [U]	21-Aug	0	0	0	0	0	0	0	0	0
	Salmon River	15-Sep	0	0	0	0	0	0	0	0	0
	Scotch Creek	4-Sep	7,822	2,750	2,046	0	4,796	4,796	302	198	1,545
	(above fence)	7-Sep	-	5,490	5,093	0	10,583	15,379	207	10	4,874
		10-Sep	-	1,545	1,738	0	3,283	18,662	24	0	1,714
		11-Sep	-	249	547	0	796	19,458	8	0	539
		15-Sep	-	1,719	2,106	0	3,825	23,283	16	1	2,089
		18-Sep	-	222	462	0	684	23,967	0	0	462
	Yard Creek	25-Aug	91	0	1	0	1	1	0	0	1
		30-Aug	526	5	4	0	9	10	0	0	4
		2-Sep	554	31	39	0	70	80	2	0	37
		5-Sep	235	80	98	0	178	258	10	0	88
		8-Sep	163	108	158	0	266	524	3	0	138
		11-Sep	62	46	74	0	120	644	2	0	72
		14-Sep	14	12	18	0	30	674	0	0	18
		17-Sep	1	2	14	0	16	690	0	0	12
South Thompson	Adams Lake	14-Oct	29	0	0	0	0	0	0	0	0
		15-Oct	439	0	0	0	0	0	0	0	0
Late Run		23-Oct	525	85	41	0	126	126	2	0	37
		27-Oct	-	76	47	0	123	249	0	0	32
		30-Oct	26	107	101	0	208	457	2	0	85
		9-Nov	-	71	98	0	169	626	0	0	96
	Anstey River	9-Oct	153	0	0	0	0	0	0	0	0
		17-Oct	401	5	1	0	6	6	0	0	1
		26-Oct	224	4	2	0	6	12	0	0	2
		1-Nov	33	0	0	0	0	12	0	0	0
		8-Nov	1	0	1	0	1	13	0	0	1
	Bush Creek	8-Oct	24	0	0	0	0	0	0	0	0
		15-Oct	160	0	0	0	0	0	0	0	0
		23-Oct	208	0	0	0	0	0	0	0	0
	Canoe Creek	13-Oct	0	0	0	0	0	0	0	0	0
		22-Oct	0	0	0	0	0	0	0	0	0
		30-Oct	0	0	0	0	0	0	0	0	0
	Celista Creek	12-Oct	0	0	0	0	0	0	0	0	0
		19-Oct	30	0	0	0	0	0	0	0	0
		29-Oct	22	0	0	0	0	0	0	0	0
		5-Nov	11	0	1	0	1	1	0	0	1
	Eagle River	13-Oct	235	0	0	0	0	0	0	0	0
	(below fence)	20-Oct	-	60	47	0	107	107	0	0	47
		21-Oct	393	0	0	0	0	107	0	0	0
		31-Oct	80	107	196	0	303	410	0	0	196

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
South Thompson	Hiuihill Creek	8-Oct	491	0	0	0	0	0	0	0	0
		16-Oct	28	9	1	0	10	10	0	0	1
Late Run		22-Oct	19	5	0	0	5	15	0	0	0
Continued		27-Oct	-	5	4	0	9	24	0	0	4
		2-Nov	0	9	7	0	16	40	0	0	7
	Hunakwa Creek	9-Oct	73	1	1	0	2	2	1	0	0
		17-Oct	149	19	9	0	28	30	1	0	8
		26-Oct	11	15	22	0	37	67	0	0	22
		1-Nov	1	9	15	0	24	91	0	0	14
	McNomee Creek	12-Oct	0	0	0	0	0	0	0	0	0
		21-Oct	0	0	0	0	0	0	0	0	0
		29-Oct	0	0	0	0	0	0	0	0	0
		5-Nov	0	0	0	0	0	0	0	0	0
	Momich River	14-Oct	46	0	0	0	0	0	0	0	0
		21-Oct	50	0	0	0	0	0	0	0	0
	Nikwikwaia Creek	8-Oct	239	2	0	0	2	2	0	0	0
		16-Oct	382	15	6	0	26 [c]	28	0	0	6
		22-Oct	220	19	12	0	31	59	0	0	12
		27-Oct	105	8	18	0	26	85	0	0	18
		2-Nov	20	0	15	0	15	100	0	0	15
	Pass Creek	8-Oct	73	17	6	0	23	23	6	0	0
		15-Oct	357	7	1	0	8	31	0	0	1
		23-Oct	459	22	4	0	26	57	2	0	2
		27-Oct	339	17	9	0	26	83	0	0	9
		2-Nov	120	13	67	0	80	163	0	0	67
		9-Nov	4	2	49	0	51	214	0	0	49
	Perry River	13-Oct	3	0	0	0	0	0	0	0	0
		1-Nov	1	0	0	0	0	0	0	0	0
	Salmon River	13-Oct	19	0	0	0	0	0	0	0	0
	(below fence)	22-Oct	133	1	2	0	3	3	1	0	1
		30-Oct	16	10	10	0	20	23	1	0	9
	Scotch Creek	8-Oct	290	17	12	0	29	29	0	0	8
		16-Oct	1,265	21	25	0	46	75	6	1	17
		22-Oct	1,434	187	151	0	338	413	3	0	57
		27-Oct	1,234	270	210	0	480	893	16	0	192
		2-Nov	637	103	101	0	204	1,097	11	0	63
		7-Nov	363	112	203	0	315	1,412	15	0	188
		10-Nov	-	101	20	0	121	1,533	4	0	16
		13-Nov	115	23	99	0	122	1,655	5	1	82
	Seymour River	12-Oct	58	0	0	0	0	0	0	0	0
		21-Oct	64	0	0	0	0	0	0	0	0
		29-Oct	2	0	0	0	0	0	0	0	0
		5-Nov	0	0	0	0	0	0	0	0	0
	S. Thompson R.	10-Oct	1,276	3	3	0	6	6	3	0	0
		17-Oct	-	120	74	0	194	200	11	4	59
		25-Oct	208	536	589	0	1,125	1,325	3	2	145
		5-Nov	-	258	187	0	445	1,770	0	0	183
	Tappen Creek	11-Oct	54	1	0	0	1	1	0	0	0
		22-Oct	92	4	2	0	6	7	0	0	2
		30-Oct	78	31	20	0	51	58	0	1	19
		10-Nov	-	10	19	0	29	87	0	0	19
	Yard Creek	13-Oct	0	0	0	0	0	0	0	0	0
		21-Oct	0	0	0	0	0	0	0	0	0
		7-Nov	-	601	820	0	1,421	1,421	1	0	818
		9-Nov	-	589	612	0	1,201	2,622	0	0	611

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
South Thompson	**Shuswap Lake**										
Late Run	Anstey Arm	9-Oct	185	0	0	0	0	0	0	0	0
Continued		18-Oct	395	0	0	0	0	0	0	0	0
		26-Oct	946	36	32	0	68	68	1	0	31
		1-Nov	83	71	81	0	152	220	1	0	80
		6-Nov	0	0	0	0	0	220	0	0	0
		8-Nov	-	38	41	0	79	299	0	0	41
	Main Arm	8-Oct	382	0	0	0	0	0	0	0	0
		16-Oct	3,067	3	6	0	9	9	6	0	0
		19-Oct	-	4	3	0	7	16	0	0	3
		22-Oct	-	86	52	0	138	154	6	1	45
		23-Oct	-	70	85	0	155	309	4	0	81
		24-Oct	1,865	45	33	0	78	387	0	1	32
		25-Oct	1,179	0	0	0	0	387	0	0	0
		26-Oct	-	422	289	0	711	1,098	19	0	152
		2-Nov	398	175	150	0	325	1,423	7	0	89
		9-Nov	2	81	72	0	153	1,576	0	0	72
	Salmon Arm	11-Oct	960	0	1	0	4 [c]	4	1	0	0
		18-Oct	1,697	0	0	0	0	4	0	0	0
		24-Oct	-	33	33	0	66	70	0	0	33
		27-Oct	-	96	95	0	191	261	1	0	94
		28-Oct	870	0	0	0	0	261	0	0	0
		6-Nov	35	49	60	0	109	370	0	0	90
		10-Nov	-	43	47	0	90	460	0	0	47
	Seymour Arm	12-Oct	0	1	0	0	1	1	0	0	0
		19-Oct	85	0	0	0	0	1	0	0	0
		5-Nov	0	3	2	0	5	6	0	0	2
	Shuswap River										
	Shuswap R., middle	13-Oct	8,372	50	57	0	107	107	0	1	56
		14-Oct	-	146	65	0	211	318	0	0	62
		15-Oct	-	155	44	0	199	517	2	2	37
		17-Oct	-	229	281	0	510	1,027	0	1	277
		18-Oct	-	281	236	0	517	1,544	1	0	144
		20-Oct	-	299	154	0	453	1,997	0	4	150
		21-Oct	-	122	280	0	402	2,399	0	0	227
		22-Oct	-	286	480	0	766	3,165	0	0	45
		23-Oct	-	155	167	0	322	3,487	0	0	131
		25-Oct	-	56	422	0	478	3,965	0	0	30
		26-Oct	-	78	230	0	308	4,273	1	0	155
		27-Oct	15	49	86	0	135	4,408	0	0	64
	Tsuius Creek	16-Oct	351	4	4	0	8	8	0	1	3
		20-Oct	260	2	5	0	7	15	0	0	5
		24-Oct	169	3	12	0	15	30	0	0	12
		28-Oct	31	0	7	0	7	37	0	0	7
	Wap Creek	17-Oct	584	7	8	0	15	15	0	0	8
		21-Oct	498	22	12	0	34	49	2	0	8
		25-Oct	286	18	21	0	39	88	0	0	20
		29-Oct	113	6	18	0	24	112	0	0	18
North Thompson	Fennell Creek	17-Aug	134	0	0	0	0	0	0	0	0
		22-Aug	2,299	3	3	0	6	6	2	0	1
		27-Aug	4,778	33	39	0	72	78	12	0	20
		1-Sep	3,786	234	332	0	566	644	7	14	205
		6-Sep	150	167	305	0	472	1,116	9	3	293
		13-Sep	134	29	49	0	78	1,194	2	0	47
	Harper Creek	30-Aug	0	0	0	0	0	0	0	0	0
		13-Sep	2	1	2	0	3	3	0	0	2

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum	0%	50%	100%
North Thompson Continued	Raft River	20-Aug	31	0	0	0	0	0	0	0	0
		24-Aug	307	0	0	0	0	0	0	0	0
		30-Aug	2,063	46	39	0	85	85	10	1	28
		4-Sep	3,297	322	310	2	634	719	33	4	273
		9-Sep	1,567	834	973	6	1,813	2,532	23	7	683
		14-Sep	581	319	403	3	725	3,257	25	3	375
Chilcotin	Elkin Creek	8-Sep	47	0	0	0	0	0	0	0	0
	Taseko Lake	10-Sep	8	6	14	0	20	20	0	2	10
Quesnel	**Horsefly River**										
	Little Horsefly River	1-Sep	221	1	0	0	1	1	0	0	0
		8-Sep	914	3	10	0	13	14	4	0	6
		16-Sep	2,018	126	161	0	287	301	24	12	120
		24-Sep	683	352	571	0	923	1,224	13	7	507
		2-Oct	63	44	68	0	112	1,336	0	0	68
	Moffat Creek	28-Aug	0	1	0	0	1	1	0	0	0
		4-Sep	0	0	0	0	0	1	0	0	0
		13-Sep	412	70	38	0	108	109	5	4	26
		20-Sep	113	198	172	0	370	479	3	2	164
		28-Sep	44	64	67	0	131	610	2	2	62
	Mitchell River										
	Cameron Creek	8-Sep	2,003	42	27	0	69	69	3	2	22
		19-Sep	4,050	749	615	0	1,364	1,433	4	3	143
		26-Sep	734	1,271	1,206	0	2,477	3,910	4	1	85
		2-Oct	46	540	632	0	1,172	5,082	1	1	88
	Penfold Creek	6-Sep	300	0	0	0	0	0	0	0	0
	Quesnel Lake, E. Arm										
	Big Slide, lakeshore	6-Sep	0	0	0	0	0	0	0	0	0
	Bill Miner Creek	6-Sep	0	0	0	0	0	0	0	0	0
		23-Sep	100	39	57	0	96	96	0	0	57
		30-Sep	17	33	32	0	65	161	0	0	32
	Bill Miner Creek, lakeshore	6-Sep	5	0	0	0	0	0	0	0	0
		23-Sep	43	0	0	0	0	0	0	0	0
		29-Sep	5	0	0	0	0	0	0	0	0
	Bill Miner Creek, lakeshore 3 km W	6-Sep	0	0	0	0	0	0	0	0	0
	Blue Lead Creek	31-Aug	470	0	1	0	1	1	0	0	0
		7-Sep	1,253	8	5	0	13	14	0	0	5
		17-Sep	1,422	131	168	0	299	313	3	1	161
		22-Sep	1,332	165	154	0	319	632	0	1	152
		29-Sep	246	131	254	0	385	1,017	0	0	251
	Blue Lead Creek, lakeshore	31-Aug	0	0	0	0	0	0	0	0	0
		6-Sep	219	0	0	0	0	0	0	0	0
		17-Sep	690	39	34	0	73	73	1	1	28
		23-Sep	390	52	61	0	113	186	2	0	49
		29-Sep	172	34	55	0	89	275	0	0	54
	Bouldery Creek	31-Aug	0	0	0	0	0	0	0	0	0
		6-Sep	0	0	0	0	0	0	0	0	0
		23-Sep	20	5	5	0	10	10	0	0	5
		30-Sep	0	1	2	0	3	13	0	0	2
	Bouldery Creek, lakeshore	31-Aug	0	0	0	0	0	0	0	0	0
		6-Sep	4	0	0	0	0	0	0	0	0
		30-Sep	5	0	0	0	0	0	0	0	0
	Bouldery Creek, lakeshore 2 km E	6-Sep	0	0	0	0	0	0	0	0	0
		23-Sep	10	0	0	0	0	0	0	0	0
	Killdog Creek	31-Aug	0	0	0	0	0	0	0	0	0
		6-Sep	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Quesnel Continued	Killdog Cr, cont'd	23-Sep	0	0	0	0	0	0	0	0	0
	Lynx Creek	31-Aug	21	0	0	0	0	0	0	0	0
		7-Sep	194	4	3	0	7	7	1	0	1
		16-Sep	264	18	33	0	51	58	1	0	25
		22-Sep	185	24	19	0	43	101	0	0	19
		30-Sep	30	3	10	0	13	114	0	0	9
	Lynx Creek, lakeshore	31-Aug	0	0	0	0	0	0	0	0	0
		6-Sep	0	0	0	0	0	0	0	0	0
		22-Sep	47	2	2	0	4	4	0	0	2
		30-Sep	7	0	0	0	0	4	0	0	0
	Niagara Creek	31-Aug	0	0	0	0	0	0	0	0	0
	Slate Bay	6-Sep	0	0	0	0	0	0	0	0	0
	Summit Creek	31-Aug	578	1	0	0	1	1	0	0	0
		6-Sep	1,835	38	8	0	46	47	3	1	4
		17-Sep	520	699	792	0	1,491	1,538	32	11	741
		23-Sep	99	157	216	0	373	1,911	2	0	214
		29-Sep	74	28	47	0	75	1,986	0	0	47
	Taku Creek	31-Aug	0	0	0	0	0	0	0	0	0
	Quesnel Lake, N. Arm										
	Bear Beach, lakehsore	3-Sep	25	0	0	0	0	0	0	0	0
		20-Sep	20	0	0	0	0	0	0	0	0
	Betty Frank's Shore	3-Sep	0	0	0	0	0	0	0	0	0
	Bowling Point lakehsore	27-Aug	0	0	0	0	0	0	0	0	0
		3-Sep	0	0	0	0	0	0	0	0	0
		10-Sep	26	0	0	0	0	0	0	0	0
		20-Sep	122	2	5	0	7	7	0	1	4
		26-Sep	30	6	9	0	15	22	0	0	9
	Deception Point lakehsore	27-Aug	4	0	0	0	0	0	0	0	0
		3-Sep	329	0	0	0	0	0	0	0	0
		10-Sep	2,320	8	7	0	15	15	0	0	6
		20-Sep	1,732	66	139	0	205	220	2	4	132
		27-Sep	390	59	144	0	203	423	0	0	114
	Devoe Creek	27-Aug	0	0	0	0	0	0	0	0	0
	Devoe Creek, lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
		20-Sep	0	0	0	0	0	0	0	0	0
	Goose Point lakeshore	27-Aug	0	0	0	0	0	0	0	0	0
		3-Sep	242	0	0	0	0	0	0	0	0
		10-Sep	620	16	18	0	34	34	1	0	11
		20-Sep	227	18	40	0	58	92	0	0	34
		26-Sep	130	61	131	0	192	284	0	0	108
	Grain Creek	27-Aug	0	0	0	0	0	0	0	0	0
		3-Sep	0	0	0	0	0	0	0	0	0
		16-Sep	105	1	0	0	1	1	0	0	0
		20-Sep	242	3	4	0	7	8	0	2	2
		27-Sep	201	17	13	0	30	38	0	0	10
		3-Oct	52	10	21	0	31	69	0	0	20
	Grain Creek, lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
		20-Sep	0	0	0	0	0	0	0	0	0
	Isaiah Creek [b]	27-Aug	0	0	0	0	0	0	0	0	0
	Limestone Point lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
		20-Sep	0	0	0	0	0	0	0	0	0
	Long Creek [b]	27-Aug	0	0	0	0	0	0	0	0	0
	Long Creek, lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
		20-Sep	0	0	0	0	0	0	0	0	0
	Marten Creek	4-Sep	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Quesnel Continued	Marten Creek, lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
		20-Sep	0	0	0	0	0	0	0	0	0
	Roaring River	27-Aug	19	0	0	0	0	0	0	0	0
		3-Sep	248	0	0	0	0	0	0	0	0
		10-Sep	486	20	19	0	39	39	4	2	9
		19-Sep	330	57	51	0	108	147	0	1	46
		26-Sep	152	44	75	0	119	266	0	0	73
	Roaring River, lakeshore	3-Sep	0	0	0	0	0	0	0	0	0
		10-Sep	30	0	0	0	0	0	0	0	0
		19-Sep	92	9	10	0	19	19	0	2	8
		27-Sep	30	10	21	0	31	50	0	0	14
	Sue Creek [c]	3-Sep	0	0	0	0	0	0	0	0	0
	Trickle Creek [c]	3-Sep	0	0	0	0	0	0	0	0	0
	Wasko Creek	27-Aug	0	0	0	0	0	0	0	0	0
		3-Sep	0	0	0	0	0	0	0	0	0
		10-Sep	642	3	1	0	4	4	0	0	1
		19-Sep	670	445	454	0	899	903	18	2	434
		27-Sep	142	262	383	0	645	1,548	3	7	308
	Watt Creek	27-Aug	0	0	0	0	0	0	0	0	0
		3-Sep	169	0	1	0	1	1	1	0	0
		10-Sep	420	4	6	0	10	11	2	1	2
		19-Sep	212	91	95	0	186	197	4	0	91
		26-Sep	27	51	103	0	154	351	0	0	66
	Quesnel Lake, W. Arm										
	Hazeltine Creek	4-Sep	0	0	0	0	0	0	0	0	0
	Raft Creek	4-Sep	0	0	0	0	0	0	0	0	0
	Spusks Creek, lakeshore	4-Sep	0	0	0	0	0	0	0	0	0
Stuart	**Driftwood River**										
Early Runs	Blackwater Creek	1-Aug	1	0	0	0	0	0	0	0	0
		7-Aug	1	0	0	0	0	0	0	0	0
		18-Aug	12	0	1	0	1	1	0	0	1
	Driftwood River	1-Aug	3,317	0	0	0	1,077 [c]	1,077	0	0	0
	Kastberg Creek	1-Aug	0	0	0	0	0	0	0	0	0
	Kotsine River	1-Aug	2	0	0	0	0	0	0	0	0
	Lion Creek	1-Aug	32	0	0	0	0	0	0	0	0
	Porter Creek	1-Aug	879	52	59	0	111	111	46	5	8
		7-Aug	402	303	299	0	602	713	132	6	161
		18-Aug	173	90	83	0	173	886	11	0	72
	Takla Lake, N.E. Arm										
	Ankwill Creek	24-Jul	170	0	0	0	0	0	0	0	0
		27-Jul	818	0	0	0	0	0	0	0	0
		30-Jul	833	1	5	0	7 [c]	7	3	0	2
		1-Aug	686	38	41	0	79	86	34	0	7
		5-Aug	686	65	80	0	145	231	48	8	24
		8-Aug	620	28	17	0	45	276	13	0	4
		11-Aug	574	26	32	0	58	334	13	0	13
		14-Aug	437	35	36	0	71	405	2	4	30
		17-Aug	197	6	12	0	18	423	7	1	4
		19-Aug	169	6	7	0	13	436	0	0	7
	Bates Creek	30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0
		8-Aug	0	0	0	0	0	0	0	0	0
	Blanchette Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	Blanchette Creek	5-Aug	0	0	0	0	0	0	0	0	0
Early Runs	cont'd	9-Aug	0	0	0	0	0	0	0	0	0
Continued		11-Aug	0	0	0	0	0	0	0	0	0
		15-Aug	0	0	0	0	0	0	0	0	0
	Forsythe Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	134	2	0	0	2	2	0	0	0
		30-Jul	246	9	6	0	16 [c]	18	4	1	1
		1-Aug	173	20	23	0	44 [c]	62	16	3	4
		5-Aug	173	28	23	0	51	113	12	1	10
		8-Aug	207	18	27	0	45	158	16	1	10
		11-Aug	169	16	23	0	39	197	7	1	15
		14-Aug	101	14	19	0	33	230	6	0	12
		17-Aug	62	3	6	0	9	239	1	0	4
		19-Aug	38	2	2	0	4	243	1	0	1
	French Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		1-Aug	2	0	0	0	0	0	0	0	0
		5-Aug	1	0	2	0	2	2	1	0	1
		8-Aug	2	0	0	0	0	2	0	0	0
		14-Aug	27	1	0	0	1	3	0	0	0
		17-Aug	38	3	5	0	8	11	4	1	0
		19-Aug	17	3	1	0	4	15	0	0	1
	Frypan Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	179	0	2	0	4 [c]	4	2	0	0
		30-Jul	273	8	12	0	22 [c]	26	12	0	0
		1-Aug	152	18	20	0	38	64	15	1	3
		5-Aug	284	37	41	0	79 [c]	143	30	0	8
		8-Aug	371	24	11	0	35	178	4	0	6
		11-Aug	394	4	12	0	17 [c]	195	1	0	7
		14-Aug	291	43	46	0	89	284	27	0	18
		17-Aug	131	24	51	0	75	359	17	0	26
		19-Aug	82	6	13	0	25 [c]	384	3	0	9
	Hudson's Bay Cr.	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		1-Aug	2	1	0	0	1	1	0	0	0
		5-Aug	0	0	0	0	0	1	0	0	0
		8-Aug	13	2	2	0	4	5	1	0	1
		11-Aug	4	0	2	0	2	7	2	0	0
		14-Aug	12	2	1	0	3	10	0	0	1
		17-Aug	18	11	4	0	15	25	2	1	0
		19-Aug	25	0	1	0	1	26	0	0	1
	Shale Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	2	0	0	0	0	0	0	0	0
		30-Jul	22	0	0	0	0	0	0	0	0
		1-Aug	45	2	0	0	2	2	0	0	0
		5-Aug	66	3	2	0	5	7	1	0	1
		9-Aug	164	0	0	0	0	7	0	0	0
		11-Aug	160	2	0	0	2	9	0	0	0
		15-Aug	163	0	0	0	0	9	0	0	0
		17-Aug	92	2	2	0	4	13	1	0	1
		19-Aug	59	1	3	0	4	17	0	1	2
	Five Mile Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	Five Mile Creek	5-Aug	0	0	0	0	0	0	0	0	0
Early Runs	cont'd	8-Aug	10	0	0	0	0	0	0	0	0
Continued		11-Aug	41	1	1	0	2	2	0	0	1
		14-Aug	51	1	0	0	1	3	0	0	0
		17-Aug	43	2	1	0	3	6	0	0	1
		19-Aug	2	1	0	0	1	7	0	0	0
	Fifteen Mile Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	1	0	0	0	1 [c]	1	0	0	0
		30-Jul	6	0	0	0	2 [c]	3	0	0	0
		2-Aug	30	2	1	0	3	6	0	0	1
		5-Aug	28	2	0	0	4 [c]	10	0	0	0
		8-Aug	82	2	0	0	2	12	0	0	0
		11-Aug	106	1	0	0	1	13	0	0	0
		15-Aug	39	2	3	0	5	18	0	0	3
		17-Aug	26	1	1	0	2	20	0	0	1
		19-Aug	24	0	1	0	1	21	0	0	1
	Ten Mile Creek [b]	24-Jul	0	0	0	0	0	0	0	0	0
	Twenty-five Mile Cr.	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	34	0	0	0	1 [c]	1	0	0	0
		30-Jul	160	3	1	0	5 [c]	6	1	0	0
		2-Aug	67	8	4	0	12	18	3	0	1
		5-Aug	97	7	7	0	14	32	4	0	2
		9-Aug	88	5	8	0	13	45	5	0	2
		11-Aug	86	2	2	0	4	49	1	0	1
		15-Aug	42	5	10	0	15	64	1	0	9
		17-Aug	29	1	4	0	5	69	0	0	4
		19-Aug	31	0	0	0	0	69	0	0	0
	Takla Lake, NW										
	Crow Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	65	0	0	0	0	0	0	0	0
		30-Jul	35	5	4	0	9	9	1	0	0
		2-Aug	27	5	8	0	13	22	1	0	7
		5-Aug	38	7	11	0	18	40	5	0	6
		8-Aug	75	2	12	0	14	54	3	1	8
		11-Aug	57	4	9	0	13	67	1	0	8
		14-Aug	55	9	23	0	32	99	5	0	18
		17-Aug	26	7	18	0	26 [c]	125	5	0	13
		20-Aug	0	2	10	0	13 [c]	138	0	0	10
	Dust Creek	27-Jul	1	0	0	0	0	0	0	0	0
		30-Jul	43	0	0	0	0	0	0	0	0
		2-Aug	-	0	0	0	0	0	0	0	0
		4-Aug	1,155	0	0	0	314 [c]	314	0	0	0
		5-Aug	1	0	0	0	0	314	0	0	0
		8-Aug	-	0	0	0	0	314	0	0	0
		11-Aug	-	0	0	0	0	314	0	0	0
	Hooker Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0
		5-Aug	0	0	0	0	0	0	0	0	0
		8-Aug	0	0	0	0	0	0	0	0	0
		11-Aug	12	1	1	0	2	2	0	0	1
		14-Aug	21	0	0	0	0	2	0	0	0
		17-Aug	21	5	3	0	8	10	1	0	2
		20-Aug	4	4	7	0	11	21	0	0	7
	McDougall Creek [b]	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	McDougall Creek	2-Aug	0	0	0	0	0	0	0	0	0
Early Runs	cont'd	5-Aug	0	0	0	0	0	0	0	0	0
Continued		8-Aug	0	0	0	0	0	0	0	0	0
		11-Aug	0	0	0	0	0	0	0	0	0
		14-Aug	0	0	0	0	0	0	0	0	0
	Point Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	87	0	0	0	0	0	0	0	0
		30-Jul	120	3	3	0	6	6	3	0	0
		2-Aug	128	10	14	0	24	30	9	2	3
		5-Aug	108	24	21	0	46 [c]	76	12	0	8
		8-Aug	167	23	18	0	41	117	8	0	10
		11-Aug	93	12	15	0	27	144	4	0	11
		14-Aug	64	8	32	0	41 [c]	185	4	0	28
		17-Aug	55	15	20	0	35	220	2	0	18
		20-Aug	9	5	7	0	12	232	1	0	2
	Sinta Creek [b]	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0
		5-Aug	0	0	0	0	0	0	0	0	0
		8-Aug	0	0	0	0	0	0	0	0	0
		11-Aug	0	0	0	0	0	0	0	0	0
		14-Aug	0	0	0	0	0	0	0	0	0
	Takla Lake, S										
	Bivouac Creek	23-Jul	0	0	0	0	0	0	0	0	0
		26-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	1	0	1	1	0	0	0
		3-Aug	0	0	0	0	0	1	0	0	0
		5-Aug	0	0	0	0	0	1	0	0	0
		9-Aug	0	2	0	0	2	3	0	0	0
		13-Aug	0	0	0	0	0	3	0	0	0
	Gluske Creek	25-Jul	205	0	0	0	0	0	0	0	0
	(above fence)	28-Jul	264	1	0	0	1	1	0	0	0
		31-Jul	276	28	23	0	63 [c]	64	8	2	13
		3-Aug	322	37	35	0	73 [c]	137	11	2	22
		6-Aug	277	46	31	0	77	214	13	0	17
		9-Aug	200	32	24	0	56	270	4	1	19
		12-Aug	130	33	21	0	54	324	1	0	20
		15-Aug	61	13	14	0	27	351	1	0	13
		18-Aug	10	6	6	0	12	12	1	0	4
	Gluske Creek	25-Jul	179	0	0	0	0	0	0	0	0
	(below fence)	28-Jul	330	1	11	0	12	12	6	2	3
		29-Jul	-	0	2	0	2	14	1	0	1
		30-Jul	-	14	11	0	25	39	9	1	1
		31-Jul	355	2	1	0	3	42	0	0	1
		2-Aug	-	1	1	0	2	44	1	0	0
		3-Aug	256	21	29	0	50	94	11	5	13
		6-Aug	179	43	31	0	74	168	15	0	15
		9-Aug	193	22	21	0	43	211	3	1	17
		12-Aug	118	27	27	0	54	265	3	0	22
		15-Aug	68	8	11	0	19	284	0	0	11
		18-Aug	19	9	10	0	19	303	3	0	6
	Leo Creek [b]	23-Jul	0	0	0	0	0	0	0	0	0
		26-Jul	0	0	0	0	0	0	0	0	0
		30-Jul	0	0	0	0	0	0	0	0	0
		2-Aug	0	0	0	0	0	0	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	Leo Creek cont'd	4-Aug	0	0	0	0	0	0	0	0	0
Early Runs	Narrows Creek	23-Jul	0	0	0	0	0	0	0	0	0
Continued		26-Jul	209	3	3	0	6	6	1	0	0
		29-Jul	289	12	20	0	33 [c]	39	13	1	6
		1-Aug	137	31	22	0	71 [c]	110	14	4	4
		4-Aug	127	9	46	0	55	165	4	0	3
		7-Aug	320	23	11	0	37 [c]	202	4	1	6
		10-Aug	257	48	34	0	82	284	12	2	20
		13-Aug	363	55	56	0	111	395	10	4	42
		16-Aug	154	28	28	0	56	451	7	1	20
		20-Aug	66	27	24	0	51	502	2	0	20
		23-Aug	16	14	13	0	27	529	1	0	12
	Sakeniche Creek	24-Jul	0	0	0	0	0	0	0	0	0
		27-Jul	2	2	15	0	17	17	11	0	1
		30-Jul	0	2	19	0	21	38	1	0	0
		2-Aug	0	0	0	0	0	38	0	0	0
		5-Aug	1	0	0	0	1 [c]	39	0	0	0
		9-Aug	0	0	0	0	0	39	0	0	0
		10-Aug	30	1	0	0	1	40	0	0	0
		13-Aug	96	13	5	0	18	58	4	1	0
		16-Aug	51	22	15	0	37	95	5	0	8
		20-Aug	5	6	4	0	10	105	0	0	4
	Sandpoint Creek	23-Jul	0	0	0	0	0	0	0	0	0
		26-Jul	16	0	0	0	0	0	0	0	0
		29-Jul	15	4	2	0	6	6	1	0	0
		1-Aug	16	1	3	0	4	10	1	0	2
		4-Aug	6	1	3	0	4	14	1	1	0
		7-Aug	13	5	1	0	6	20	1	0	0
		10-Aug	17	5	2	0	7	27	0	0	2
		13-Aug	17	0	0	0	0	27	0	0	0
		16-Aug	28	0	0	0	1 [c]	28	0	0	0
		20-Aug	18	3	1	0	4	32	0	0	1
	Middle River										
	Forfar Creek	25-Jul	6	0	0	0	0	0	0	0	0
	(above fence)	28-Jul	69	1	0	0	1	1	0	0	0
		31-Jul	194	0	0	0	0	1	0	0	0
		3-Aug	221	0	17	0	28 [c]	29	5	0	3
		6-Aug	372	8	11	0	19	48	5	2	4
		9-Aug	299	15	20	0	35	83	9	0	11
		12-Aug	246	60	25	0	85	168	10	0	15
		15-Aug	199	42	29	0	71	239	5	0	23
		18-Aug	39	11	21	0	32	271	2	0	19
	Forfar Creek	25-Jul	283	2	3	0	5	5	2	0	1
	(below fence)	28-Jul	303	1	5	0	6	11	4	0	1
		30-Jul	-	9	12	0	21	32	10	1	1
		31-Jul	381	4	6	0	10	42	6	0	0
		2-Aug	-	0	0	1	1	43	0	0	0
		3-Aug	301	15	11	0	26	69	7	1	3
		6-Aug	359	12	16	0	28	97	8	3	5
		9-Aug	249	11	10	0	21	118	4	0	6
		12-Aug	198	24	29	0	53	171	14	0	15
		15-Aug	94	24	21	0	45	216	3	0	18
		18-Aug	45	13	10	0	23	239	2	0	7
	Kazchek Creek	3-Aug	0	0	0	0	0	0	0	0	0
		10-Aug	5	1	1	0	2	2	0	0	1
		12-Aug	1	0	0	0	0	2	0	0	0

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	Kynoch Creek	22-Jul	80	0	1	0	1	1	0	0	0
Early Runs	(above fence)	25-Jul	383	1	1	0	2	3	0	0	0
Continued		28-Jul	645	9	11	0	23 [c]	26	11	0	0
		31-Jul	618	66	73	0	139	165	46	1	24
		3-Aug	631	89	129	0	218	383	88	0	37
		6-Aug	481	104	105	0	209	592	55	0	50
		9-Aug	397	95	51	0	165 [c]	757	27	0	24
		12-Aug	210	95	82	0	205 [c]	962	9	0	50
		15-Aug	158	33	26	0	70 [c]	1,032	7	2	15
		18-Aug	75	17	17	0	34	1,066	3	0	12
	Kynoch Creek	21-Jul	94	3	1	0	4	4	1	0	0
	(below fence)	22-Jul	18	0	2	0	2	6	2	0	0
		23-Jul	-	6	4	0	10	16	4	0	0
		25-Jul	328	4	4	0	8	24	4	0	0
		28-Jul	334	8	16	0	24	48	13	0	3
		30-Jul	-	3	4	0	7	55	4	0	0
		31-Jul	234	5	8	0	13	68	8	0	0
		2-Aug	-	18	16	1	35	103	15	0	1
		3-Aug	182	18	22	0	40	143	15	1	4
		6-Aug	145	22	11	1	34	177	9	0	2
		9-Aug	147	15	16	0	31	208	7	0	6
		12-Aug	135	6	11	0	17	225	1	0	10
		15-Aug	129	3	1	0	4	229	0	0	1
		18-Aug	71	8	14	0	22	251	3	1	10
	Middle River	3-Aug	0	0	0	0	0	0	0	0	0
		4-Aug	0	0	0	0	0	0	0	0	0
		12-Aug	15	0	0	0	0	0	0	0	0
	Rossette Creek	22-Jul	29	3	0	0	12 [c]	12	0	0	0
		25-Jul	182	1	2	0	3	15	1	0	0
		28-Jul	379	7	6	0	13	28	6	0	0
		31-Jul	401	36	32	0	70 [c]	98	16	4	4
		3-Aug	267	58	36	0	94	192	16	3	15
		4-Aug	-	6	14	0	20	212	6	0	8
		6-Aug	200	26	48	0	104 [c]	316	9	1	34
		9-Aug	112	54	46	0	137 [c]	453	4	0	23
		12-Aug	88	37	31	0	68	521	3	1	22
		15-Aug	66	11	2	0	33 [c]	554	0	0	1
		18-Aug	47	11	13	0	28 [c]	582	3	0	9
	Trembleur Lake										
	Felix Creek	19-Jul	0	0	0	0	0	0	0	0	0
		23-Jul	143	0	0	0	0	0	0	0	0
		26-Jul	400	1	0	0	1	1	0	0	0
		29-Jul	689	26	20	0	46	47	14	1	5
		1-Aug	721	82	95	0	178 [c]	225	36	3	53
		4-Aug	579	121	140	0	262 [c]	487	45	2	93
		7-Aug	517	117	131	0	248	735	45	0	86
		10-Aug	398	88	90	0	178	913	32	0	56
		13-Aug	175	84	125	0	210 [c]	1,123	24	0	93
		16-Aug	109	55	78	0	133	1,256	14	0	59
	Fleming Creek	4-Aug	33	0	0	0	0	0	0	0	0
	Paula Creek	19-Jul	0	0	0	0	0	0	0	0	0
		23-Jul	0	0	0	0	0	0	0	0	0
		26-Jul	0	0	0	0	0	0	0	0	0
		29-Jul	16	0	0	0	0	0	0	0	0
		1-Aug	189	1	2	0	9 [c]	9	2	0	0
		4-Aug	256	7	7	0	16 [c]	25	5	0	2
		7-Aug	361	18	16	0	34	59	6	1	9

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Stuart	Paula Creek	10-Aug	252	26	24	0	50	109	4	3	16
Early Runs	cont'd	13-Aug	161	67	59	0	126	235	13	0	46
Continued		16-Aug	62	57	44	0	101	336	5	0	35
Stuart	Kazchek Creek	28-Aug	4	0	0	0	0	0	0	0	0
Summer Runs		2-Sep	6	0	0	0	0	0	0	0	0
		3-Sep	14	0	0	0	0	0	0	0	0
		6-Sep	4	0	0	0	0	0	0	0	0
		17-Sep	450	2	5	0	7	7	2	0	3
		22-Sep	1,196	13	22	0	35	42	0	0	16
		28/98	310	24	25	0	49	91	1	0	19
		1-Oct	165	37	49	0	86	177	0	0	47
	Pinchi Creek	2-Sep	0	0	0	0	0	0	0	0	0
		8-Sep	20	1	0	0	1	1	0	0	0
		16-Sep	487	2	3	0	5	6	0	0	3
		24-Sep	587	55	95	0	150	156	14	0	81
		30-Sep	255	79	114	0	193	349	4	0	110
		3-Oct	149	29	41	0	70	419	0	0	41
	Sakeniche River	17-Sep	54	0	1	0	1	1	0	0	1
		25-Sep	14	0	1	0	1	2	0	0	0
		29-Sep	0	0	3	0	3	5	0	0	0
	Sowchea Creek	8-Sep	0	0	0	0	0	0	0	0	0
		16-Sep	0	0	0	0	0	0	0	0	0
		24-Sep	0	0	0	0	0	0	0	0	0
Nechako	Nadina River	12-Sep	161	0	0	0	0	0	0	0	0
		19-Sep	422	0	0	0	0	0	0	0	0
	Stellako River [b]	31-Aug	-	0	0	0	0	0	0	0	0
		4-Sep	-	0	0	0	0	0	0	0	0
		7-Sep	-	0	0	0	0	0	0	0	0
		11-Sep	-	0	1	0	1	1	1	0	0
		14-Sep	-	2	2	0	4	5	2	0	0
		18-Sep	-	2	1	0	3	8	1	0	0
		19-Sep	-	3	7	0	10	18	6	0	1
		20-Sep	-	6	14	0	20	38	9	0	4
		22-Sep	-	8	12	0	20	58	4	0	8
		23-Sep	-	61	58	0	119	177	29	0	26
		25-Sep	-	68	130	0	198	375	19	0	107
		26-Sep	-	85	137	0	222	597	18	0	114
		28-Sep	-	513	458	2	973	1,570	25	0	425
		29-Sep	-	653	1,009	1	1,663	3,233	51	4	941
		1-Oct	-	2,091	2,165	1	4,257	7,490	32	4	2,108
		2-Oct	-	1,074	1,521	0	2,595	10,085	23	14	1,464
		3-Oct	-	1,196	1,443	3	2,642	12,727	32	0	1,396
		4-Oct	-	3,311	2,994	0	6,305	19,032	27	4	2,916
		5-Oct	-	2,318	2,554	2	4,874	23,906	48	18	2,466
		6-Oct	-	1,710	1,853	1	3,564	27,470	34	8	1,788
		7-Oct	-	4,617	4,551	4	9,172	36,642	33	17	4,463
		8-Oct	-	2,307	2,555	0	4,862	41,504	7	8	2,520
		9-Oct	-	2,751	3,403	4	6,158	47,662	21	16	3,338
		10-Oct	-	3,127	3,262	2	6,391	54,053	21	8	3,210
		11-Oct	-	2,340	2,926	0	5,266	59,319	19	16	2,875
		12-Oct	-	1,832	2,103	0	3,935	63,254	11	9	2,070
		13-Oct	-	2,569	3,089	1	5,659	68,913	3	7	3,046
		14-Oct	-	1,494	1,982	0	3,476	72,389	6	0	1,961
		15-Oct	-	937	1,247	0	2,184	74,573	0	0	1,244
		16-Oct	-	855	1,002	0	1,857	76,430	0	0	999

Continued

Appendix 9. Daily live counts, male, female and jack carcass recoveries, and female spawning success, by stock group, stock and date, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock group	Stock	Date	Live count	Carcasses recovered					% spawned		
				Male	Female	Jack	Total	Cum.	0%	50%	100%
Upper Fraser	Bowron River	28-Aug	930	0	0	0	0	0	0	0	0
		3-Sep	2,527	0	0	0	127 [C]	127	0	0	0
		4-Sep	-	74	109	1	184	311	0	0	109
	Indianpoint Creek	3-Sep	0	0	0	0	0	0	0	0	0

[A] Includes one recovery field identified as a jack which scale evaluation confirmed as an adult.

[B] Live counts are fish let above the barrier.

[C] Includes unsexed dead recorded but not sampled during a live enumeration survey.

[D] Creek dry; no sockeye access.

[E] Low water; no sockeye access.

[F] Beaver dams blocked access.

[G] Includes five recoveries field identified as a jack which scale evaluation confirmed as an adult.

Appendix 10. Number of surveys, peak live counts, cumulative dead counts, expansion factors, spawning success, and escapement of sockeye adults (by sex) and jacks, by stock group and stock, for Fraser River sockeye salmon assessed using visual surveys, 1998.

Stock Group	Stock	Number of surveys	Peak live	Cumulative dead	Expansion factor	Weighted percent spawning success	Source of sex ratio[A]	Escapement estimate		
								Male	Female	Jack
Lower Fraser	Chilliwack Lake	5	0	268	4.0	67.1%	-	436	632	4
	Nahatlatch Lake	3	1	235	6.7	40.7%	-	780	787	0
	Nahatlatch River	4	3,437	133	1.8	82.3%	-	2,947	3,479	0
	Widgeon Slough	4	34	5	1.8	80.0%	-	48	22	0
Harrison-Lillooet	Big Silver Creek	4	3,018	304	1.8	94.8%	-	2,846	3,128	6
	Green River	1	0	0	-	-	-	0	0	0
	Harrison River	8	5,482	16	1.8	99.0%	-	1,453	3,043	0
	Poole Creek	2	117	0	1.8	95.0%	-	105	106	0
	Samson Creek	3	335	11	1.8	95.7%	-	256	367	0
Seton-Anderson	Gates Creek	17[B]	1,097	0	-	54.2%	-	694	242	161
	Portage Creek	4	13,491	512	1.8	90.5%	-	12,060	13,119	26
South Thompson *Early Summer Runs*	Adams Channel	6	219	0	1.8	75.0%	-[C]	210	184	0
	Adams River, lower	10	843	12	1.8	95.0%	-[C]	821	718	0
	Adams River, upper	5	123	68	1.8	96.2%	-	180	164	0
	Anstey River	6	2,571	63	1.8	93.5%	-	2,382	2,359	0
	Cayenne Creek	5	86	4	1.8	84.7%	-	59	103	0
	Celista Creek	2	0	0	1.8	-	-	0	0	0
	Hiuihill Creek	4	425	45	1.8	90.3%	-	450	394	2
	Hunakwa Creek	2	0	0	1.8	-	-	0	0	0
	Malakwa Creek	5	41	1	1.8	90.0%	-	19	57	0
	McNomee Creek	8	358	14	1.8	90.7%	-	328	342	0
	Momich River	2	0	0	1.8	-	-	0	0	0
	Nikwikwaia Creek	3	126	6	1.8	83.3%	-[C]	127	111	0
	Onyx Creek	1	0	0	1.8	-	-	0	0	0
	Perry River	8	319	9	1.8	100.0%	-	209	381	0
	Ross Creek	1	0	0	1.8	-	-	0	0	0
	Salmon River	1	0	0	-	-	-	0	0	0
	Scotch Cr., above	6	7,822	4,796	-	94.5%	-	17,962	18,019	12
	Yard Creek	8	554	80	1.8	95.7%	-	470	671	0
South Thompson *Late Runs*	Adams Lake	6	525	126	1.8	98.5%	-	635	537	0
	Adams River, upper	-[D]	0	0	1.8	-	-	0	0	0
	Anstey River	5	401	6	1.8	100.0%	-	507	226	0
	Bush Creek	3	208	0	1.8	98.5%	-[E]	203	171	0
	Canoe Creek	3	0	0	1.8	-	-	0	0	0
	Celista Creek	4	30	0	1.8	100.0%	-[F]	30	24	0
	Eagle River[G]	4	393	107	1.8	100.0%	-	367	533	0
	Hiuihill Creek	5	491	0	1.8	100.0%	-	619	265	0
	Hunakwa Creek	4	149	30	1.8	95.7%	-	156	166	0
	McNomee Creek	4	0	0	1.8	-	-	0	0	0
	Momich River	2	50	0	1.8	98.5%	-[E]	49	41	0
	Nikwikwaia Creek	5	382	28	1.8	100.0%	-	342	396	0
	Pass Creek	6	459	57	1.8	94.1%	-	339	590	0
	Perry River	2	3	0	1.8	100.0%	-[H]	2	3	0
	Salmon River[I]	3	133	3	1.8	83.3%	-	102	143	0
	Scotch Creek	8	1,434	413	1.8	91.4%	-	1,675	1,650	0
	Seymour River	4	64	0	1.8	91.3%	-[F]	65	50	0
	S. Thompson R.	4	1,276	6	1.8	96.3%	-	1,196	1,112	0
	Tappen Creek	4	92	7	1.8	98.8%	-	94	84	0
	Yard Creek	2	0	0	1.8	-	-	0	0	0

Continued

Appendix 10. Number of surveys, peak live counts, cumulative dead counts, expansion factors, spawning success, and escapement of sockeye adults (by sex) and jacks, by stock group and stock, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock Group	Stock	Number of surveys	Peak live	Cumulative dead	Expansion factor	Weighted percent spawning success	Source of sex ratio[A]	Escapement estimate		
								Male	Female	Jack
South Thompson	**Shuswap Lake**									
Late Runs	Anstey Arm	6	946	68	1.8	98.7%	-	885	940	0
Continued	Main Arm	10	3,067	9	1.8	91.3%	-	3,113	2,424	0
	Salmon Arm	7	1,697	4	1.8	99.2%	-	1,481	1,581	0
	Seymour Arm	3	85	1	1.8	100.0%	-[F]	57	68	0
	Shuswap River									
	Shuswap R., middle	12	8,372	107	1.8	99.6%	-	6,599	8,663	0
	Tsuius Creek	4	351	8	1.8	98.2%	-[I]	318	328	0
	Wap Creek	4	584	15	1.8	95.9%	-	510	568	0
North Thompson	Fennell Creek	6	4,778	78	1.8	93.2%	-	3,411	5,330	0
	Harper Creek	2	2	3	1.8	100.0%	-	3	6	0
	Raft River	6	3,297	719	1.8	93.7%	-	3,373	3,825	31
Chilcotin	Elkin Creek	1[J]	47	0	1.8	91.7%[K]	-[K]	25	60	0
	Taseko Lake	1	8	20	14.3	91.7%	-	120	280	0
Quesnel	**Horsefly River**									
	Little Horsefly River	5	2,018	301	1.8	93.5%	-	1,643	2,531	0
	Moffat Creek	5	412	109	1.8	94.7%	-	512	426	0
	Mitchell River									
	Cameron Creek	4	4,050	1,433	1.8	96.1%	-	5,053	4,816	0
	Penfold Creek	1	300	0	1.8	93.7%[L]	-[L]	258	282	0
	Quesnel Lake, E. Arm									
	Big Slide lakeshore	1	0	0	1.8	-	-	0	0	0
	Bill Miner Creek	3	100	96	1.8	100.0%	-	158	195	0
	Bill Miner lakeshore	3	43	0	1.8	100.0%[M]	-[M]	34	43	0
	Bill Miner, 3km W	1	0	0	1.8	-	-	0	0	0
	Blue Lead Creek	5	1,422	313	1.8	99.1%	-	1,336	1,787	0
	Blue Lead lakeshore	5	690	73	1.8	97.3%	-	624	749	0
	Bouldery Creek	4	20	10	1.8	100.0%	-	25	29	0
	Bouldery lakeshore	3	5	0	1.8	100.0%[N]	-[N]	4	5	0
	Bouldery, 2 km E	2	10	0	1.8	100.0%[N]	-[N]	8	10	0
	Killdog Creek	3	0	0	1.8	-	-	0	0	0
	Lynx Creek	5	264	58	1.8	95.7%	-	249	331	0
	Lynx lakeshore	4	47	4	1.8	100.0%	-	40	52	0
	Niagara Creek	1	0	0	1.8	-	-	0	0	0
	Slate Bay	1	0	0	1.8	-	-	0	0	0
	Summit Creek	5	1,835	47	1.8	95.9%	-	1,575	1,813	0
	Taku Creek	1	0	0	1.8	-	-	0	0	0
	Quesnel Lake, N. Arm									
	Bear Beach lakeshore	2	25	0	1.8	99.2%[O]	-[O]	15	30	0
	Betty Frank's Shore	1	0	0	1.8	-	-	0	0	0
	Bowling Point	5	122	7	1.8	96.4%	-	84	148	0
	Deception Point	5	2,320	15	1.8	98.6%	-	1,322	2,881	0
	Devoe Creek	1	0	0	1.8	-	-	0	0	0
	Devoe lakeshore	2	0	0	1.8	-	-	0	0	0
	Goose Point	5	620	34	1.8	99.2%	-	394	783	0
	Grain Creek	6	242	8	1.8	97.4%	-	202	248	0
	Grain lakeshore	2	0	0	1.8	-	-	0	0	0
	Isaiah Creek	1	0	0	1.8	-	-	0	0	0
	Limestone Point	2	0	0	1.8	-	-	0	0	0

Continued

Appendix 10. Number of surveys, peak live counts, cumulative dead counts, expansion factors, spawning success, and escapement of sockeye adults (by sex) and jacks, by stock group and stock, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock Group	Stock	Number of surveys	Peak live	Cumulative dead	Expansion factor	Weighted percent spawning success	Source of sex ratio[A]	Escapement estimate		
								Male	Female	Jack
Quesnel Continued	Long Creek	1	0	0	1.8	-	-	0	0	0
	Long lakeshore	2	0	0	1.8	-	-	0	0	0
	Marten Creek	1	0	0	1.8	-	-	0	0	0
	Marten lakeshore	2	0	0	1.8	-	-	0	0	0
	Roaring River	5	486	39	1.8	95.3%	-	430	515	0
	Roaring lakeshore	4	92	19	1.8	96.8%	-	76	124	0
	Sue Creek	1	0	0	1.8	-	-	0	0	0
	Trickle Creek	1	0	0	1.8	-	-	0	0	0
	Wasko Creek	5	670	903	1.8	96.8%	-	1,298	1,533	0
	Watt Creek	5	420	11	1.8	96.1%	-	323	453	0
	Quesnel Lake Tributaries - West Arm									
	Hazeltine Creek	1	0	0	1.8	-	-	0	0	0
	Raft Creek	1	0	0	1.8	-	-	0	0	0
	Spusks Cr lakeshore	1	0	0	1.8	-	-	0	0	0
Stuart	**Driftwood River**									
Early Runs	Blackwater Creek	3	12	1	2.1	100.0%	-[P]	14	13	0
	Driftwood River	1	3,317	1,077	2.1	55.9%[P]	-[P]	4,635	4,592	0
	Kastberg Creek	1	0	0	2.1	-	-	0	0	0
	Kotsine River	1	2	0	2.1	55.9%[P]	-[P]	2	2	0
	Lion Creek	1	32	0	2.1	55.9%[P]	-[P]	34	33	0
	Porter Creek	3	879	111	2.1	55.9%	-	1,044	1,035	0
	Takla Lake, N.E. Arm									
	Ankwill Creek	10	833	7	2.1	43.7%	-	831	933	0
	Bates Creek	3	0	0	2.1	-	-	0	0	0
	Blanchette Creek	8	0	0	2.1	-	-	0	0	0
	Forsythe Creek	10	246	18	2.1	48.0%	-	257	297	0
	French Creek	9	38	11	2.1	31.3%	-	48	55	0
	Frypan Creek	10	394	195	2.1	42.5%	-	545	692	0
	Hudson's Bay Cr.	10	25	26	2.1	36.7%	-	66	41	0
	Shale Creek	10	164	7	2.1	64.3%	-[Q]	174	185	0
	Five Mile Creek	10	51	3	2.1	100.0%	-[Q]	55	58	0
	Fifteen Mile Creek	10	106	13	2.1	100.0%	-[Q]	121	129	0
	Ten Mile Creek	1	0	0	2.1	-	-	0	0	0
	Twenty-five Mile Cr.	10	160	6	2.1	54.5%	-	161	188	0
	Takla Lake, N.W. Arm									
	Crow Creek	10	75	54	2.1	74.2%	-	82	189	0
	Dust Creek	7	1,155	314	2.1	52.9%[Q]	-[Q]	1,492	1,591	0
	Hooker Creek	10	21	10	2.1	90.9%	-	31	34	0
	McDougall Creek	7	0	0	2.1	-	-	0	0	0
	Point Creek	10	167	117	2.1	64.7%	-	259	337	0
	Sinta Creek	8	0	0	2.1	-	-	0	0	0
	Takla Lake, S. Arm									
	Bivouac Creek	8	0	3	2.1	0.0%	-	4	2	0
	Gluske Cr., above	9	322	137	-	72.6%	-	453	358	1
	Gluske Cr., below	12	108	265	1.8	62.9%	-	328	343	0
	Leo Creek	5	0	0	2.1	-	-	0	0	0
	Narrows Creek	11	363	395	2.1	61.5%	-	785	807	0
	Sakeniche River	10	96	58	2.1	38.4%	-	102	221	0
	Sandpoint Creek	10	28	28	2.1	47.9%	-	72	46	0

Continued

Appendix 10. Number of surveys, peak live counts, cumulative dead counts, expansion factors, spawning success, and escapement of sockeye adults (by sex) and jacks, by stock group and stock, for Fraser River sockeye salmon assessed using visual surveys, 1998 continued.

Stock Group	Stock	Number of surveys	Peak live	Cumulative dead	Expansion factor	Weighted percent spawning success	Source of sex ratio[A]	Escapement estimate		
								Male	Female	Jack
Stuart	**Middle River**									
Early Runs	Forfar Cr., above	9	372	48	-	65.2%	-	546	407	3
Continued	Forfar Cr., below	12	131	171	2.3	49.0%	-	333	357	3
	Kazchek Creek	3	5	2	2.1	100.0%	-	7	8	0
	Kynock Cr., above	10	631	383	-	47.9%	-	1,059	1,207	4
	Kynoch Cr., below	14	124	229	2.2	30.6%	-	367	401	9
	Middle River	3	15	0	2.1	64.7% [R]	- [R]	17	15	0
	Rossette Creek	11	401	98	2.1	64.7%	-	546	502	0
	Trembleur Lake									
	Felix Creek	10	721	225	2.1	68.0%	-	910	1,077	0
	Fleming Creek	1	33	0	2.1	68.0% [S]	- [S]	36	42	0
	Paula Creek	10	361	59	2.1	75.2%	-	473	409	0
Stuart	Kazchek Creek	8	1,196	42	1.8	96.8%	-	957	1,271	0
Summer Runs	Pinchi Creek	6	587	156	1.8	92.9%	-	530	807	0
	Sakeniche River.	3	54	1	1.8	98.6% [T]	- [T]	49	50	0
	Sowchea Creek	3	0	0	1.8	-	-	0	0	0
Nechako	Nadina River	2	422	0	1.8	95.6% [U]	- [U]	333	423	4
Upper Fraser	Bowron River	3	2,527	127	1.8	100.0%	-	1,921	2,830	26
	Indianpoint Creek	1	0	0	1.8	-	-	0	0	0

[A] Noted only when insufficient survey data were available for that stock.
[B] Total let above barrier
[C] Hiuihill Creek estimate.
[D] SNFC coho surveys; no sockeye were observed.
[E] Adams Lake estimate.
[F] Shuswap Lake Main Arm estimate.
[G] Below fence estimate, see Appendix 3.
[H] Eagle River estimate
[I] Lower Shuswap River estimate.
[J] Data provided by C&P
[K] Taseko Lake estimate.
[L] Mitchell River estimate.
[M] Bill Miner Creek estimate.
[N] Bouldery Creek estimate.
[O] Goose Point Shore estimate.
[P] Porter Creek estimates.
[Q] Takla Lake stocks composite estimate.
[R] Rossette Creek estimate.
[S] Felix Creek estimate.
[T] Middle River estimate.
[U] Nadina Channel estimate.

Appendix 11. Period of peak spawning, adult and jack escapement, spawning success, and the number of females that spawned successfully, by stock group, stock and estimation method, for Fraser River sockeye salmon, 1998.

Stock Group	Stock	Period of peak spawning	Escapement					Percent spawning success	Effective females	Estimation method
			Total	Adults	Jacks	Males	Females			
Lower Fraser	Chilliwack Lake	Early Sep	1,072	1,068	4	436	632	67.1%	424	Visual
	Cultus Lake	Early Dec	2,166	1,959	207	928	1,031	62.5%	644	Fence
	Nahatlatch Lake	07-Sep to 12-Sep	1,567	1,567	0	780	787	40.7%	320	Visual
	Nahatlatch River	07-Sep to 12-Sep	6,426	6,426	0	2,947	3,479	82.3%	2,865	Visual
	Pitt River, upper	15-Sep to 20-Sep	76,888	76,888	0	27,753	49,135	96.9%	47,612	M.R.
	Widgeon Slough	18-Nov to 24-Nov	70	70	0	48	22	80.0%	18	Visual
	Total	-	**88,189**	**87,978**	**211**	**32,892**	**55,086**	**94.2%**	**51,883**	-
Harrison-Lillooet	Big Silver Creek	Late Sep	5,980	5,974	6	2,846	3,128	94.8%	2,967	Visual
	Birkenhead River	22-Sep to 27-Sep	296,038	295,669	369	114,299	181,370	95.4%	172,997	M.R.
	Green River	-	0	0	0	0	0	-	0	Visual
	Harrison River	10-Nov to 15-Nov	4,496	4,496	0	1,453	3,043	99.0%	3,013	Visual
	Poole Creek	22-Sep to 27-Sep	211	211	0	105	106	95.0%	101	Visual
	Samson Creek	22-Sep to 27-Sep	623	623	0	256	367	95.7%	351	Visual
	Weaver Channel	11-Oct to 16-Oct	29,117	29,071	46	11,733	17,338	94.6%	16,409	Census
	Weaver Creek	11-Oct to 16-Oct	28,042	28,020	22	13,188	14,832	90.4%	13,402	M.R.
	Total	-	**364,507**	**364,064**	**443**	**143,680**	**220,184**	**95.0%**	**209,240**	-
Seton-Anderson	Gates Channel	29-Aug to 02-Sep	7,628	6,312	1,316	2,573	3,739	61.8%	2,311	Census
	Gates Creek	29-Aug to 02-Sep	1,097	936	161	694	242	54.2%	131	Visual
	Portage Creek	25-Oct to 30-Oct	25,205	25,179	26	12,060	13,119	90.5%	11,873	Visual
	Total	-	**33,930**	**32,427**	**1,503**	**15,327**	**17,100**	**83.7%**	**14,315**	-
South Thompson *Early Summer Runs*	Adams Channel	05-Sep to 10-Sep	394	394	0	210	184	75.0%	138	Visual
	Adams R., lower	05-Sep to 10-Sep	1,539	1,539	0	821	718	95.0%	682	Visual
	Adams R., upper	02-Sep to 07-Sep	344	344	0	180	164	96.2%	158	Visual
	Anstey River	03-Sep to 08-Sep	4,741	4,741	0	2,382	2,359	93.5%	2,205	Visual
	Cayenne Creek	02-Sep to 07-Sep	162	162	0	59	103	84.7%	87	Visual
	Celista Creek	-	0	0	0	0	0	-	0	Visual
	Eagle River	05-Sep to 10-Sep	28,478	28,478	0	12,321	16,157	97.1%	15,661	M.R.
	Hiuihill Creek	31-Aug to 05-Sep	846	844	2	450	394	90.3%	356	Visual
	Hunakwa Creek	-	0	0	0	0	0	-	0	Visual
	Malakwa Creek	30-Aug to 05-Sep	76	76	0	19	57	90.0%	51	Visual
	McNomee Creek	02-Sep to 06-Sep	670	670	0	328	342	90.7%	310	Visual
	Momich River	-	0	0	0	0	0	-	0	Visual
	Nikwikwaia Creek	02-Sep to 07-Sep	238	238	0	127	111	83.3%	92	Visual
	Onyx Creek	-	0	0	0	0	0	-	0	Visual
	Perry River	05-Sep to 10-Sep	590	590	0	209	381	100.0%	381	Visual
	Ross Creek	-	0	0	0	0	0	-	0	Visual
	Salmon River	-	0	0	0	0	0	-	0	Visual
	Scotch Creek	30-Aug to 03-Sep	35,993	35,981	12	17,962	18,019	94.5%	17,001	Fence
	Seymour River	06-Sep to 08-Sep	33,389	33,378	11	18,604	14,774	96.7%	14,238	M.R.
	Yard Creek	05-Sep to 10-Sep	1,141	1,141	0	470	671	95.7%	642	Visual
	Total	-	**108,601**	**108,576**	**25**	**54,142**	**54,434**	**95.5%**	**52,002**	-
South Thompson *Late Runs*	Adams Lake	18-Oct to 25-Oct	1,172	1,172	0	635	537	98.5%	529	Visual
	Adams R., lower	18-Oct to 25-Oct	871,184	870,919	265	411,951	458,968	95.7%	439,185	M.R.
	Adams R., upper	-	0	0	0	0	0	-	0	Visual
	Anstey River	15-Oct to 20-Oct	733	733	0	507	226	100.0%	226	Visual
	Bush Creek	21-Oct to 28-Oct	374	374	0	203	171	98.5%	168	Visual
	Canoe Creek	-	0	0	0	0	0	-	0	Visual
	Celista Creek	18-Oct to 25-Oct	54	54	0	30	24	100.0%	24	Visual
	Eagle River	Early Oct	11,398	11,398	0	5,812	5,586	100.0%	5,586	Fence
	Hiuihill Creek	15-Oct to 22-Oct	884	884	0	619	265	100.0%	265	Visual
	Hunakwa Creek	15-Oct to 20-Oct	322	322	0	156	166	95.7%	159	Visual
	Little River	18-Oct to 25-Oct	176,252	176,205	47	95,371	80,834	91.9%	74,278	M.R.
	McNomee Creek	-	0	0	0	0	0	-	0	Visual
	Momich River	-	90	90	0	49	41	98.5%	40	Visual
	Nikwikwaia Creek	15-Oct to 22-Oct	738	738	0	342	396	100.0%	396	Visual
	Pass Creek	21-Oct to 28-Oct	929	929	0	339	590	94.1%	555	Visual
	Perry River	-	5	5	0	2	3	100.0%	3	Visual
	Salmon River	Late Oct	326	326	0	156	170	83.3%	142	Fence
	Scotch Creek	20-Oct to 26-Oct	3,325	3,325	0	1,675	1,650	91.4%	1,508	Visual
	Seymour River	18-Oct to 24-Oct	115	115	0	65	50	91.3%	48	Visual

Continued

Appendix 11. Period of peak spawning, adult and jack escapement, spawning success, and the number of females that spawned successfully, by stock group, stock and estimation method, for Fraser River sockeye salmon, 1998 continued.

Stock Group	Stock	Period of peak spawning	Escapement					Percent spawning success	Effective females	Estimation method
			Total	Adults	Jacks	Males	Females			
South Thompson	S. Thompson R.	15-Oct to 20-Oct	2,308	2,308	0	1,196	1,112	96.3%	1,071	Visual
Late Runs continued	Tappen Creek	20-Oct to 26-Oct	178	178	0	94	84	98.8%	83	Visual
	Yard Creek	-	0	0	0	0	0	-	0	Visual
	Shuswap Lake									
	Anstey Arm	20-Oct to 27-Oct	1,825	1,825	0	885	940	98.7%	928	Visual
	Main Arm	20-Oct to 26-Oct	5,537	5,537	0	3,113	2,424	91.3%	2,213	Visual
	Salmon Arm	20-Oct to 27-Oct	3,062	3,062	0	1,481	1,581	99.2%	1,568	Visual
	Seymour Arm	20-Oct to 27-Oct	155	155	0	87	68	100.0%	68	Visual
	Shuswap River									
	Shuswap R., lower	12-Oct to 16-Oct	291,631	291,631	0	142,094	149,537	95.0%	142,013	M.R.
	Shuswap R., middle	09-Oct to 15-Oct	15,262	15,262	0	6,599	8,663	99.6%	8,631	Visual
	Tsuius Creek	15-Oct to 19-Oct	646	646	0	318	328	98.2%	322	Visual
	Wap Creek	15-Oct to 19-Oct	1,078	1,078	0	510	568	95.9%	545	Visual
	Total	-	**1,389,583**	**1,389,271**	**312**	**674,289**	**714,982**	**95.2%**	**680,552**	-
North Thompson	Fennell Creek	27-Aug to 01-Sep	8,741	8,741	0	3,411	5,330	93.2%	4,966	Visual
	Harper Creek	-	9	9	0	3	6	100.0%	6	Visual
	Raft River	30-Aug to 09-Sep	7,229	7,198	31	3,373	3,825	93.7%	3,585	Visual
	Total	-	**15,979**	**15,948**	**31**	**6,787**	**9,161**	**93.4%**	**8,557**	-
Chilcotin	Chilko River and Lake	25-Sep to 05-Oct	880,944	879,010	1,934	367,336	511,674	91.4%	467,624	M.R.
	Elkin Creek	-	85	85	0	25	60	91.7%	55	Visual
	Taseko Lake	Early Sep	400	400	0	120	280	91.7%	257	Visual
	Total	-	**881,429**	**879,495**	**1,934**	**367,481**	**512,014**	**91.4%**	**467,936**	-
Quesnel	**Horsefly River**									
	Horsefly Channel	-	24,934	24,934	0	11,760	13,174	89.1%	11,735	Census
	Horsefly River	07-Sep to 17-Sep	743,122	743,122	0	373,601	369,521	87.1%	321,883	M.R.
	Little Horsefly River	16-Sep to 25-Sep	4,174	4,174	0	1,643	2,531	93.5%	2,366	Visual
	McKinley Creek	07-Sep to 17-Sep	75,829	75,829	0	37,892	37,937	74.9%	28,430	Fence
	Moffat Creek	13-Sep to 20-Sep	938	938	0	512	426	94.7%	403	Visual
	Mitchell River									
	Cameron Creek	18-Sep to 25-Sep	9,869	9,869	0	5,053	4,816	96.1%	4,627	Visual
	Mitchell River	18-Sep to 25-Sep	299,920	299,920	0	136,240	163,680	93.7%	153,370	M.R.
	Penfold Creek	-	540	540	0	258	282	93.7%	264	Visual
	Quesnel Lake, E. Arm									
	Big Slide lakeshore	-	0	0	0	0	0	-	0	Visual
	Bill Miner Creek	20-Sep to 30-Sep	353	353	0	158	195	100.0%	195	Visual
	Bill Miner lakeshore	20-Sep to 26-Sep	77	77	0	34	43	100.0%	43	Visual
	Bill Miner, 3km W		0	0	0	0	0	-	0	Visual
	Blue Lead Creek	14-Sep to 22-Sep	3,123	3,123	0	1,336	1,787	99.1%	1,771	Visual
	Blue Lead lakeshore	14-Sep to 22-Sep	1,373	1,373	0	624	749	97.3%	729	Visual
	Bouldery Creek	20-Sep to 26-Sep	54	54	0	25	29	100.0%	29	Visual
	Bouldery lakeshore	-	9	9	0	4	5	100.0%	5	Visual
	Bouldery, 2 km E		18	18	0	8	10	100.0%	10	Visual
	Killdog Creek	-	0	0	0	0	0	-	0	Visual
	Lynx Creek	14-Sep to 22-Sep	580	580	0	249	331	95.7%	317	Visual
	Lynx lakeshore	20-Sep to 26-Sep	92	92	0	40	52	100.0%	52	Visual
	Niagara Creek	-	0	0	0	0	0	-	0	Visual
	Slate Bay	-	0	0	0	0	0	-	0	Visual
	Summit Creek	02-Sep to 12-Sep	3,388	3,388	0	1,575	1,813	95.9%	1,739	Visual
	Taku Creek	-	0	0	0	0	0	-	0	Visual
	Quesnel Lake, N. Arm									
	Bear Beach lakeshore	-	45	45	0	15	30	99.2%	30	Visual
	Betty Frank's lakeshore	-	0	0	0	0	0	-	0	Visual
	Bowling Point	16-Sep to 24-Sep	232	232	0	84	148	96.4%	143	Visual
	Deception Point	10-Sep to 20-Sep	4,203	4,203	0	1,322	2,881	98.6%	2,841	Visual
	Devoe Creek	-	0	0	0	0	0	-	0	Visual
	Devoe lakeshore	-	0	0	0	0	0	-	0	Visual
	Goose Point	10-Sep to 20-Sep	1,177	1,177	0	394	783	99.2%	777	Visual
	Grain Creek	20-Sep to 30-Sep	450	450	0	202	248	97.4%	241	Visual
	Grain lakeshore	-	0	0	0	0	0	-	0	Visual
	Isaiah Creek	-	0	0	0	0	0	-	0	Visual
	Limestone Point	-	0	0	0	0	0	-	0	Visual

Continued

Appendix 11. Period of peak spawning, adult and jack escapement, spawning success, and the number of females that spawned successfully, by stock group, stock and estimation method, for Fraser River sockeye salmon, 1998 continued.

Stock Group	Stock	Period of peak spawning	Escapement					Percent spawning success	Effective females	Estimation method
			Total	Adults	Jacks	Males	Females			
Quesnel	Long Creek	-	0	0	0	0	0	-	0	Visual
continued	Long Creek lakeshore	-	0	0	0	0	0	-	0	Visual
	Marten Creek	-	0	0	0	0	0	-	0	Visual
	Roaring River	10-Sep to 20-Sep	945	945	0	430	515	95.3%	491	Visual
	Roaring lakeshore	15-Sep to 23-Sep	200	200	0	76	124	96.8%	120	Visual
	Sue Creek	-	0	0	0	0	0	-	0	Visual
	Trickle Creek	-	0	0	0	0	0	-	0	Visual
	Wasko Creek	10-Sep to 20-Sep	2,831	2,831	0	1,298	1,533	96.8%	1,484	Visual
	Watt Creek	10-Sep to 20-Sep	776	776	0	323	453	96.1%	435	Visual
	Watt lakeshore	-	0	0	0	0	0	-	0	Visual
	Quesnel Lake, W. Arm									
	Hazeltine Creek	-	0	0	0	0	0	-	0	Visual
	Raft Creek	-	0	0	0	0	0	-	0	Visual
	Spusks Cr. lakeshore	-	0	0	0	0	0	-	0	Visual
	Total	-	**1,179,252**	**1,179,252**	**0**	**575,156**	**604,096**	**88.5%**	**534,530**	-
Stuart	**Driftwood River**									
Early Runs	Blackwater River	-	27	27	0	14	13	100.0%	13	Visual
	Driftwood River	-	9,227	9,227	0	4,635	4,592	55.9%	2,567	Visual
	Kastberg Creek	-	0	0	0	0	0	-	0	Visual
	Kotsine River	-	4	4	0	2	2	55.9%	1	Visual
	Lion Creek	-	67	67	0	34	33	55.9%	18	Visual
	Porter Creek	01-Aug to 07-Aug	2,079	2,079	0	1,044	1,035	55.9%	579	Visual
	Takla Lake, N.E. Arm									
	Ankwill Creek	30-Jul to 11-Aug	1,764	1,764	0	831	933	43.7%	408	Visual
	Bates Creek	-	0	0	0	0	0	-	0	Visual
	Blanchette Creek	-	0	0	0	0	0	-	0	Visual
	Forsythe Creek	30-Jul to 11-Aug	554	554	0	257	297	48.0%	143	Visual
	French Creek	14-Aug to 18-Aug	103	103	0	48	55	31.3%	17	Visual
	Frypan Creek	30-Jul to 14-Aug	1,237	1,237	0	545	692	42.5%	294	Visual
	Hudson's Bay Cr.	14-Aug to 19-Aug	107	107	0	66	41	36.7%	15	Visual
	Shale Creek	09-Aug to 15-Aug	359	359	0	174	185	64.3%	119	Visual
	Five Mile Creek	11-Aug to 17-Aug	113	113	0	55	58	100.0%	58	Visual
	Fifteen Mile Creek	08-Aug to 14-Aug	250	250	0	121	129	100.0%	129	Visual
	Ten Mile Creek	-	0	0	0	0	0	-	0	Visual
	Twenty-five Mile Cr.	30-Jul to 11-Aug	349	349	0	161	188	54.5%	102	Visual
	Takla Lake, N.W. Arm									
	Crow Creek	08-Aug to 15-Aug	271	271	0	82	189	74.2%	140	Visual
	Dust Creek	08-Aug to 15-Aug	3,083	3,083	0	1,492	1,591	52.9%	842	Visual
	Hooker Creek	14-Aug to 17-Aug	65	65	0	31	34	90.9%	31	Visual
	McDougall Creek	-	0	0	0	0	0	-	0	Visual
	Point Creek	01-Aug to 15-Aug	596	596	0	259	337	64.7%	218	Visual
	Sinta Creek	-	0	0	0	0	0	-	0	Visual
	Takla Lake, S. Arm									
	Bivouac Creek	-	6	6	0	4	2	0.0%	0	Visual
	Gluske Creek	31-Jul to 09-Aug	1,508	1,507	1	781	726	67.7%	475	Fence
	Leo Creek	-	0	0	0	0	0	-	0	Visual
	Narrows Creek	29-Jul to 15-Aug	1,592	1,592	0	785	807	61.5%	496	Visual
	Sakeniche River	12-Aug to 17-Aug	323	323	0	102	221	38.4%	85	Visual
	Sandpoint Creek	01-Aug to 17-Aug	118	118	0	72	46	47.9%	22	Visual
	Middle River									
	Forfar Creek	06-Aug to 15-Aug	1,674	1,668	6	879	789	57.1%	436	Fence
	Kazchek Creek	07-Aug to 11-Aug	15	15	0	7	8	100.0%	8	Visual
	Kynock Creek	28-Jul to 05-Aug	3,072	3,059	13	1,426	1,633	44.4%	713	Fence
	Middle River	-	32	32	0	17	15	64.7%	10	Visual
	Rossette Creek	31-Jul to 06-Aug	1,048	1,048	0	546	502	64.7%	325	Visual
	Trembleur Lake									
	Felix Creek	29-Jul to 05-Aug	1,987	1,987	0	910	1,077	68.0%	732	Visual
	Fleming Creek	-	78	78	0	36	42	68.0%	29	Visual
	Paula Creek	04-Aug to 11-Aug	882	882	0	473	409	75.2%	307	Visual
	Total	-	**32,590**	**32,570**	**20**	**15,889**	**16,681**	**56.2%**	**9,332**	-

Continued

Appendix 11. Period of peak spawning, adult and jack escapement, spawning success, and the number of females that spawned successfully, by stock group, stock and estimation method, for Fraser River sockeye salmon, 1998 continued.

Stock Group	Stock	Period of peak spawning	Escapement					Percent spawning success	Effective females	Estimation method
			Total	Adults	Jacks	Males	Females			
Stuart	Kazchek Creek	18-Sep to 25-Sep	2,228	2,228	0	957	1,271	96.8%	1,230	Visual
Summer	Kuzkwa River	20-Sep to 28-Sep	2,867	2,864	3	1,393	1,471	98.3%	1,446	Fence
Runs	Middle River	18-Sep to 24-Sep	38,917	38,906	11	19,400	19,506	98.6%	19,236	M.R.
	Pinchi Creek	20-Sep to 28-Sep	1,337	1,337	0	530	807	92.9%	750	Visual
	Sakeniche River.	20-Sep to 28-Sep	99	99	0	49	50	98.6%	49	Visual
	Sowchea Creek	-	0	0	0	0	0	-	0	Visual
	Tachie River	26-Sep to 02-Oct	93,973	92,963	1,010	47,066	45,897	98.4%	45,122	M.R.
	Total	-	**139,421**	**138,397**	**1,024**	**69,395**	**69,002**	**98.3%**	**67,833**	-
Nechako	Nadina Channel	20-Sep to 25-Sep	2,964	2,949	15	1,299	1,650	95.6%	1,578	Census
	Nadina River	20-Sep to 25-Sep	760	756	4	333	423	95.6%	405	Visual
	Stellako River	26-Sep to 05-Oct	185,697	185,641	56	87,273	98,368	98.6%	96,961	Fence
	Total	-	**189,421**	**189,346**	**75**	**88,905**	**100,441**	**98.5%**	**98,944**	-
Upper	Bowron River	Early Sep	4,777	4,751	26	1,921	2,830	100.0%	2,830	Visual
Fraser	Indianpoint Creek	-	0	0	0	0	0	-	0	Visual
	Total		**4,777**	**4,751**	**26**	**1,921**	**2,830**	**100.0%**	**2,830**	
Total	**Early Runs**	-	**32,590**	**32,570**	**20**	**15,889**	**16,681**	**55.9%**	**9,332**	-
	Early Summer Runs	-	**228,244**	**226,662**	**1,582**	**99,810**	**126,852**	**94.1%**	**119,347**	-
	Summer Runs	-	**2,385,314**	**2,382,300**	**3,014**	**1,099,160**	**1,283,140**	**90.9%**	**1,166,948**	-
	Late Runs	-	**1,781,531**	**1,780,543**	**988**	**831,205**	**949,338**	**95.0%**	**902,327**	-
	Total	-	**4,427,679**	**4,422,075**	**5,604**	**2,046,064**	**2,376,011**	**92.5%**	**2,197,954**	-